DECLARATION

I, Hikaru MORIOKA, 1-17, Uchiya 3-chome, Minami-ku, Saitama-shi, Saitama, Japan, do hereby declare that I am familiar with the English and Japanese Languages and that I believe the annexed is an accurate translation of the certified copy of the Japanese Patent Application No.2002-247338, filed on August 27, 2002.

This 15th day of November, 2004

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JAPANESE PATENT OFFICE

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【NEED FOR PROOF】 Necessary

【TITLE OF THE DOCUMENT】 SPECIFICATION

【TITLE OF THE INVENTION】 BARREL-ADVANCING CAM MECHANISM OF A ZOOM LENS, AND BARREL-ADVANCING CAM MECHANISM

【CLAIMS】

1. A barrel-advancing cam mechanism of a zoom lens which includes: a rotatable cam ring having a plurality of cam grooves formed on a peripheral surface of said cam ring; and a linearly movable ring movable by said cam ring along an optical axis without rotating by engagement of said plurality of cam grooves with a plurality of cam followers of said linearly movable ring when said cam ring is rotated, said linearly movable ring supporting at least one optical element of a photographing optical system,

wherein said plurality of cam grooves are located at different positions at least in said optical axis direction and which trace substantially a same reference cam diagram, while all cam grooves of said plurality of cam grooves are partial cam grooves each having at least one end opening at at least one of opposite ends of said cam ring, so as not to include an entire portion of said

reference cam diagram,

wherein said plurality of cam followers are located at different positions at least in said optical axis direction and are respectively engageable in said plurality of cam grooves, and

wherein at least one of said plurality of cam followers remains engaged in a corresponding said cam groove while at least one of the other of said plurality of cam followers comes out of said end opening and is disengaged therefrom, when said linearly movable ring moves to at least one of opposite limits for movement thereof in said optical axis direction.

2. The barrel-advancing cam mechanism according to claim 1, wherein said plurality of cam grooves comprises a front cam groove having at least one front end opening at a front end of said cam ring so as not to include a front part of said entire portion of said reference cam diagram, and a rear cam groove having at least one rear end opening at a rear end of said cam ring so as not to include a rear part of said entire portion of said reference cam diagram,

wherein said cam followers comprise a front cam follower and a rear cam follower which are engaged in said front cam groove and said rear cam groove, respectively,

wherein said front cam follower comes out of said

front opening to be disengaged from said front cam groove while said rear cam follower remains engaged in said rear cam groove when said linearly movable ring moves to a front limit for movement thereof in said optical axis direction, and

wherein said rear cam follower comes out of said rear opening to be disengaged from said rear cam groove while said front cam follower remains engaged in said front cam groove when said linearly movable ring moves to a rear limit for movement thereof in said optical axis direction.

3. The barrel-advancing cam mechanism according to claim 1 or 2, further comprising:

a plurality of cam groove groups, each said cam groove group comprising said plurality of cam grooves located at different positions in said optical axis direction, said plurality of cam groove groups located at different positions in a circumferential direction of said cam ring; and

a plurality of cam follower groups, each said cam follower group comprising said complementing cam followers provided at different positions in said optical axis direction, said plurality of cam follower groups located at different positions in a circumferential direction of said linearly movable ring.

4. A lens-barrel-advancing cam mechanism of a zoom lens which includes: a rotatable cam ring having a pair of cam grooves formed on a peripheral surface of said cam ring; and a linearly movable ring movable by said cam ring along an optical axis without rotating by engagement of said pair of cam grooves with a pair of cam followers of said linearly movable ring when said cam ring is rotated, said linearly movable ring supporting at least one optical element of a photographing optical system,

wherein said pair of cam grooves are located at different positions at least in said optical axis direction and which trace substantially a same reference cam diagram, while said pair of cam grooves are partial cam grooves each having at least one end opening at at least one of opposite ends of said cam ring, so as not to include an entire portion of said reference cam diagram,

wherein said pair of cam followers are located at different positions at least in said optical axis direction and are respectively engageable in said pair of cam grooves, and

wherein one of said pair of cam followers remains engaged in a corresponding said cam groove while the other of said pair of cam followers comes out of said end opening and is disengaged therefrom, when said linearly

movable ring moves to at least one of opposite limits for movement thereof in said optical axis direction.

5. A barrel-advancing cam mechanism including: a rotatable cam ring having a plurality of cam grooves formed on a peripheral surface of said cam ring; and a linearly movable ring movable by said cam ring along a rotational axis of said cam ring without rotating by engagement of said plurality of cam grooves with a plurality of cam followers of said linearly movable ring when said cam ring is rotated,

wherein said plurality of cam grooves are located at different positions at least in said rotational axis direction and which trace substantially a same reference cam diagram, while all cam grooves of said plurality of cam grooves are partial cam grooves each having at least one end opening at at least one of opposite ends of said cam ring, so as not to include an entire portion of said reference cam diagram,

wherein said plurality of cam followers are located at different positions at least in said rotational axis direction and are respectively engageable in said plurality of cam grooves, and

wherein at least one of said plurality of cam followers remains engaged in a corresponding said cam groove while at least one of the other of said plurality

of cam followers comes out of said end opening and is disengaged therefrom, when said linearly movable ring moves to at least one of opposite limits for movement thereof in said rotational axis direction.

【DETAILED DESCRIPTION OF THE INVENTION】

【0001】

【Technical Field】

The present invention relates to a barrel-advancing cam mechanism using a cam ring and a linearly movable ring, and more specifically to a lens moving mechanism of a zoom lens which uses a cam ring.

【0002】

【Prior Art and Problems Thereof】

Miniaturization of cameras has been in increasing demand. In a retractable lens barrel which advances and retracts one or more lens groups by rotation of a cam ring, it has been desired to reduce the length of the cam ring while securing a sufficient range of movement of each movable lens group in an optical axis direction. In addition, a barrel-advancing cam mechanism which satisfies such an antinomic demand has also been desired in technical fields other than the technical field of zoom lenses.

【0003】

【Objective of the Invention】

An object of the present invention is to provide a barrel-advancing cam mechanism, having a cam ring and used in a zoom lens, wherein the cam mechanism incorporates a small cam ring without sacrificing the range of movement of one or more movable lens groups. Another object of the present invention is to provide a barrel-advancing cam mechanism, having a cam ring, wherein the cam mechanism incorporates a small cam ring without sacrificing the range of movement of the linearly movable member.

【0004】

【Summary of the Invention】

A barrel-advancing cam mechanism of a zoom lens according to the present invention has been made on the premise that the barrel-advancing cam mechanism includes: a rotatable cam ring having a plurality of cam grooves formed on a peripheral surface of the cam ring; and a linearly movable ring movable by the cam ring along an optical axis without rotating by engagement of the plurality of cam grooves with a plurality of cam followers of the linearly movable ring when the cam ring is rotated, the linearly movable ring supporting at least one optical element of a photographing optical system. The plurality of cam grooves are located at different positions at least in the optical axis direction and

which trace substantially a same reference cam diagram, while all cam grooves of the plurality of cam grooves are partial cam grooves each having at least one end opening at at least one of opposite ends of the cam ring, so as not to include an entire portion of the reference cam diagram. On the other hand, the plurality of cam followers are located at different positions at least in the optical axis direction and are respectively engageable in the plurality of cam grooves. And also, at least one of the plurality of cam followers remains engaged in a corresponding the cam groove while at least one of the other of the plurality of cam followers comes out of the end opening and is disengaged therefrom, when the linearly movable ring moves to at least one of opposite limits for movement thereof in the optical axis direction. This structure makes it possible to give the linearly movable ring an amount of movement greater than the length of the cam ring in the optical axis direction. The cam mechanism can operate if only it is provided with at least one pair of cam grooves and corresponding at least one pair of cam followers.

【0005】

More preferably, the plurality of cam grooves comprises a front cam groove having at least one front end opening at a front end of the cam ring so as not to

include a front part of the entire portion of the reference cam diagram, and a rear cam groove having at least one rear end opening at a rear end of the cam ring so as not to include a rear part of the entire portion of the reference cam diagram, wherein the cam followers comprise a front cam follower and a rear cam follower which are engaged in the front cam groove and the rear cam groove, respectively, wherein the front cam follower comes out of the front opening to be disengaged from the front cam groove while the rear cam follower remains engaged in the rear cam groove when the linearly movable ring moves to a front limit for movement thereof in the optical axis direction, and wherein the rear cam follower comes out of the rear opening to be disengaged from the rear cam groove while the front cam follower remains engaged in the front cam groove when the linearly movable ring moves to a rear limit for movement thereof in the optical axis direction.

【0006】

To support the linearly movable ring with stability, it is desirable that the barrel-advancing cam mechanism further includes: a plurality of cam groove groups, each cam groove group comprising the plurality of cam grooves located at different positions in the optical axis direction, the plurality of cam groove

groups located at different positions in a circumferential direction of the cam ring; and a plurality of cam follower groups, each cam follower group comprising the complementing cam followers provided at different positions in the optical axis direction, the plurality of cam follower groups located at different positions in a circumferential direction of the linearly movable ring.

【0007】

The present invention can also be applied to various barrel-advancing cam mechanisms of any technical fields other than the technical field of the zoom lenses, by making the linearly movable ring support a member other than one or more optical elements of a photographing optical system.

【0008】

【Embodiment】

Firstly, the overall structure of an embodiment of a zoom lens 71 according to the present invention will be hereinafter described below with reference to Figures 1 through 18. This embodiment of the zoom lens 71 is incorporated in a digital camera 70, and is provided with a photographing optical system consisting of a first lens group LG1, a shutter S, an adjustable diaphragm A, a second lens group LG2, a third lens group LG3, a low-pass

filter (and the like) LG4, and a solid-state image pick-up device (CCD) 60. "Z1" shown in the drawings designates the optical axis of the photographing optical system. The photographing optical axis Z1 is parallel to a lens barrel axis Z0 of the zoom lens 71, and is decentered with respect to the lens barrel axis Z0. In the following descriptions, the term "optical axis direction" means a direction parallel to the photographing optical axis Z1 unless there is a different explanatory note on the expression.

【0009】

As shown in Figures 6 and 7, the camera 70 is provided in the camera body 72 thereof with a stationary barrel 22 fixed to the camera body 72, and a CCD holder 21 fixed to a rear portion of the stationary barrel 22. The CCD image sensor 60 is mounted to the CCD holder 21 to be held thereby via a CCD base plate 62. The low-pass filter LG4 is held by the CCD holder 21 to be positioned in front of the solid-state image pick-up device 60 via a filter holder 73 and an annular sealing member 61.

【0010】

The zoom lens 71 is provided in the stationary barrel 22 with an AF lens frame (a third lens frame which supports and holds the third lens group LG3) 51 which is guided linearly in the optical axis direction without

rotating about the photographing optical axis Z1. Specifically, the zoom lens 71 is provided with a pair of AF guide shafts 52 and 53 which extend parallel to the photographing optical axis Z1 to guide the AF lens frame 51 in the optical axis direction without rotating the AF lens frame 51 about the photographing optical axis Z1. Front and rear ends of each guide shaft of the pair of AF guide shafts 52 and 53 are fixed to the stationary barrel 22 and the CCD holder 21, respectively. The pair of AF guide shafts 52 and 53 are respectively fitted into a pair of guide holes so that the AF lens frame 51 is slidable on the pair of AF guide shafts 52 and 53. In this particular embodiment, the AF guide shaft 52 serves as a main guide shaft, while the AF guide shaft 53 serves as a member for preventing the AF lens frame 51 from rotating. An AF motor 160 having a rotary drive shaft is threaded to serves as a feed screw shaft, and this rotary drive shaft is screwed through a screw hole formed on an AF nut 54 fixed to the AF lens frame 51. Due to this structure, rotating the rotary drive shaft forward and rearward causes the AF lens frame 51 to move forward and rearward in the optical axis direction by engagement of the rotary drive shaft (feed screw shaft) with the AF nut 54. The AF lens frame 51 is biased forward in the optical axis direction by an AF-frame biasing spring 55.

【0011】

As shown in Figure 5, a zoom motor 150 and a reduction gear train box 74 are mounted on the stationary barrel 22. The reduction gear train box 74 contains a reduction gear train for transferring rotation of the zoom motor 150 to a zoom gear 28. The zoom gear 28 is pivoted to the stationary barrel 22 by a zoom gear shaft 29 which extends parallel to the photographing optical axis Z1. Rotations of the zoom motor 150 and the AF motor 160 are controlled by a control circuit of the digital camera via a flexible PWB (printed wiring board) 75 which is positioned on an outer peripheral surface of the stationary barrel 22.

【0012】

The stationary barrel 22 is provided on an inner peripheral surface thereof with a female helicoid 22a, a set of three linear guide grooves 22b, a set of three lead grooves 22c, and a set of three rotational sliding grooves 22d. The set of three linear guide grooves 22b extend parallel to the photographing optical axis Z1. The set of three lead grooves 22c extend parallel to the female helicoid 22a. The set of three rotational sliding grooves 22d are formed in the vicinity of a front end of the inner peripheral surface of the stationary barrel 22 to extend along a circumference of the

stationary barrel 22 to communicate the front ends of the set of three lead grooves 22c, respectively. The female helicoid 22a is not formed on that specific front area of the stationary barrel 22 on which the set of three rotational sliding grooves 22d are formed.

【0013】

A helicoid ring 18 is provided on an outer peripheral surface thereof with a male helicoid 18a and a set of three rotational sliding projections 18b. The male helicoid 18a is engaged with the female helicoid 22a, and the set of three rotational sliding projections 18b are engaged in the set of three lead grooves 22c or the set of three rotational sliding grooves 22d, respectively (see Figures 4 and 12). The helicoid ring 18 is provided on threads of the male helicoid 18a with an annular gear 18c which is in mesh with the zoom gear 28. Therefore, when a rotation of the zoom gear 28 is transferred to the annular gear 18c, the helicoid ring 18 moves forward or rearward in the optical axis direction while rotating within a predetermined range in which the female helicoid 22a remains in mesh with the male helicoid 18a. A forward movement of the helicoid ring 18 beyond a predetermined point causes the annular gear 18c to be disengaged from the zoom gear 28 so that the helicoid ring 18 rotates about the lens barrel axis

Z0 without moving in the optical axis direction relative to the zoom gear 28 by engagement of the set of three rotational sliding projections 18b with the set of three rotational sliding grooves 22d. The stationary barrel 22 is provided with a stop-member insertion hole 22e which radially penetrates one rotational sliding groove 22d and an outer peripheral surface of the stationary barrel 22. A barrel stop member 26 for preventing the helicoid ring 18 from rotating beyond a photographing range thereof is detachably attached to the stop-member insertion hole 22e.

【0014】

The helicoid ring 18 is provided, on an inner front peripheral surface thereof at three different circumferential positions on the helicoid ring 18, with three rotation transfer recesses 18d (see Figures 4 and 10), while the third external barrel 15 is provided, at corresponding three different circumferential positions on the third external barrel 15, with three pairs of rotation transfer projections 15a (see Figures 4 and 11) which project rearward from the rear end of the third external barrel 15 to be inserted into the three rotation transfer recesses 18d from the front thereof, respectively. The three pairs of rotation transfer projections 15a and the three rotation transfer recesses

18d are movable relative to each other in a direction of the lens barrel axis Z0, and are not rotatable relative to each other about the lens barrel axis Z0. Namely, the helicoid ring 18 and the third external barrel 15 rotate in one piece. The helicoid ring 18 is provided on the three rotational sliding projections 18b with a set of three engaging recesses 18e which are formed on an inner peripheral surface of the helicoid ring 18. The third external barrel 15 is provided with a set of three engaging projections 15b which are engaged in the set of three engaging recesses 18e, respectively. The set of three engaging projections 15b, which are respectively engaged in the set of three engaging recesses 18e, are also engaged in the set of three rotational sliding grooves 22d at a time, respectively, when the set of three rotational sliding projections 18b are engaged in the set of three rotational sliding grooves 22d (see an upper half of the zoom lens in Figure 6).

【0015】

The zoom lens 70 is provided between the third external barrel 15 and the helicoid ring 18 with three compression coil springs 25 which bias the third external barrel 15 and the helicoid ring 18 in opposite directions away from each other in the optical axis direction. The rear ends of the three compression coil springs 25 are

respectively inserted into three spring insertion recesses 18f which are formed on the front end of the helicoid ring 18, while the front ends of the three compression coil springs 25 are respectively in pressing contact with three engaging recesses 15c formed at the rear end of the third external barrel 15. Therefore, the set of three engaging projections 15b of the third external barrel 15 are respectively pressed against front surfaces in the set of three rotational sliding grooves 22d by the spring force of the three compression coil springs 25, while the set of three rotational sliding projections 18b of the helicoid ring 18 are respectively pressed against rear guide surfaces in the set of three rotational sliding grooves 22d by the spring force of the three compression coil springs 25. This removes backlash of the third external barrel 15 and the helicoid ring 18 with respect to the stationary barrel 22.

【0016】

The third external barrel 15 is provided on an inner peripheral surface thereof with a plurality of relative rotation guide projections 15d which are formed at different circumferential positions on the third external barrel 15, a circumferential groove 15e which extends in a circumferential direction about the lens

barrel axis Z0, and a set of three rotation transfer grooves 15f which extend parallel to the lens barrel axis Z0 (see Figures 4 and 11). The circumferential positions of the three rotation transfer grooves 15f are formed to correspond to those of the three pairs of rotation transfer projections 15a, respectively. The rear end of each rotation transfer groove 15f is open at the rear end of the third external barrel 15. The helicoid ring 18 is provided on an inner peripheral surface thereof with a circumferential groove 18g which extends in a circumferential direction about the lens barrel axis Z0 (see Figures 4 and 10). The zoom lens is provided inside the third external barrel 15 and the helicoid ring 18 with a first linear guide ring 14. The first linear guide ring 14 is provided on an outer peripheral surface thereof with a set of three linear guide projections 14a, a first plurality of relative rotation guide projections 14b, a second plurality of relative rotation guide projections 14c, and a circumferential groove 14d in this order from rear to front of the first linear guide ring 14 in the optical axis direction (see Figures 4 and 12). The set of three linear guide projections 14a project radially outwards. The first plurality of relative rotation guide projections 14b project radially outwards at different

circumferential positions on the first linear guide ring 14, and the second plurality of relative rotation guide projections 14c project at different circumferential positions on the first linear guide ring 14. The circumferential groove 14d is an annular groove with its center on the lens barrel axis Z0. The first linear guide ring 14 is guided in the optical axis direction with respect to the stationary barrel 22 by engagement of the set of three linear guide projections 14a with the set of three linear guide grooves 22b, respectively. The third external barrel 15 is coupled to the first linear guide ring 14 to be rotatable about the lens barrel axis Z0 relative to the first linear guide ring 14 by both the engagement of the second plurality of relative rotation guide projections 14c with the circumferential groove 15e and the engagement of the plurality of relative rotation guide projections 15d with the circumferential groove 14d. The second plurality of relative rotation guide projections 14c and the circumferential groove 15e are engaged with each other to be slightly movable relative to each other in the optical axis direction. Likewise, the plurality of relative rotation guide projections 15d and the circumferential groove 14d are engaged with each other to be slightly movable relative to each other in the optical axis direction. The

helicoid ring 18 is coupled to the first linear guide ring 14 to be rotatable about the lens barrel axis Z0 relative to the first linear guide ring 14 by engagement of the first plurality of relative rotation guide projections 14b with the circumferential groove 18g. The first plurality of relative rotation guide projections 14b and the circumferential groove 18g are engaged with each other to be slightly movable relative to each other in the optical axis direction.

【0017】

The first linear guide ring 14 is provided with a set of three guide slots 14e which radially penetrate the first linear guide ring 14. As shown in Figure 12, each guide slot 14e includes a front circumferential slot portion 14e-1, a rear circumferential slot portion 14e-2, and a lead slot portion 14e-3 which connects the front circumferential slot portion 14e-1 with the rear circumferential slot portion 14e-2. The front circumferential slot portion 14e-1 and the rear circumferential slot portion 14e-2 extend parallel to each other in a circumferential direction of the first linear guide ring 14. The lead slot portion 14e-3 extends parallel to the threads of the female helicoid 22a. A set of three followers 32 fixed to an outer peripheral surface of a cam ring 11 at different

circumferential positions thereon are engaged in the set of three guide lots 14e, respectively. Each roller follower 32 is fixed to the cam ring 11 by set screw 32a. The set of three followers 32 are further engaged in the set of three rotation transfer grooves 15f through the set of three guide lots 14e, respectively. A set of three follower pressing protrusions 17a protrude rearward from a roller-biasing spring 17 to be engaged in front portions of the set of three rotation transfer grooves 15f, respectively (see Figure 11). The set of three follower pressing protrusions 17a press the set of three followers 32 rearward to remove backlash between the set of three followers 32 and the set of three guide lots 14e when the set of three followers 32 are engaged in the front circumferential slot portions 14e-1 of the set of three guide lots 14e, respectively.

【0018】

Advancing operations of movable elements of the zoom lens 71 from the stationary barrel 22 to the cam ring 11 will be understood with reference to the above described structure of the digital camera 70. Namely, rotating the zoom gear 28 in a lens barrel advancing direction by the zoom motor 150 causes the helicoid ring 18 to move forward while rotating about the lens barrel axis Z0 due to engagement of the female helicoid 22a with

the male helicoid 18a. This rotation of the helicoid ring 18 causes the third external barrel 15 to move forward together with the helicoid ring 18 while rotating about the lens barrel axis Z0 together with the helicoid ring 18, and further causes the first linear guide ring 14 to move forward together with the helicoid ring 18 and the third external barrel 15 because each of the helicoid ring 18 and the third external barrel 15 is coupled to the first linear guide ring 14 to make respective relative rotations between the third external barrel 15 and the first linear guide ring 14 and between the helicoid ring 18 and the first linear guide ring 14 possible and to be movable together along a direction of a common rotational axis (i.e., the lens barrel axis Z0) due to the engagement of the first plurality of relative rotation guide projections 14b with the circumferential groove 18g, the engagement of the second plurality of relative rotation guide projections 14c with the circumferential groove 15e and the engagement of the plurality of relative rotation guide projections 15d with the circumferential groove 14d. Rotation of the third external barrel 15 is transferred to the cam ring 11 via the set of three rotation transfer grooves 15f and the set of three followers 32, which are engaged in the set of three rotation transfer grooves 15f,

respectively. Since the set of three followers 32 are also engaged in the set of three guide lots 14e, respectively, the cam ring 11 moves forward while rotating about the lens barrel axis Z0 relative to the first linear guide ring 14 in accordance with contours of the lead slot portions 14e-3 of the set of three guide lots 14e. Since the first linear guide ring 14 itself moves forward together with the third lens barrel 15 and the helicoid ring 18 as described above, the cam ring 11 moves forward in the optical axis direction by an amount of movement corresponding to the sum of the amount of the forward movement of the first linear guide ring 14 and the amount of the forward movement of the cam ring 11 by engagement of the set of three followers 32 with the lead slot portions 14e-3 of the set of three guide lots 14e, respectively.

【0019】

The above described rotating-advancing operations are performed while the set of three rotational sliding projections 18b are moving in the set of three lead grooves 22c, respectively, when the male helicoid 18a and the female helicoid 22a are engaged with each other. When the helicoid ring 18 moves forward by a predetermined amount of movement, the male helicoid 18a and the female helicoid 22a are disengaged from each

other so that the set of three rotational sliding projections 18b move from the set of three lead grooves 22c to the set of three rotational sliding grooves 22d, respectively, while the set of three followers 32 enter the front circumferential slot portions 14e-1 of the set of three guide lots 14e, respectively. Since the helicoid ring 18 does not move in the optical axis direction relative to the stationary barrel 22 even if rotating upon the disengagement of the male helicoid 18a from the female helicoid 22a, the helicoid ring 18 and the third external barrel 15 rotate at respective axial fixed positions thereof without moving in the optical axis direction. In this state, since the first linear guide ring 14 stops while the set of three followers 32 have respectively moved into the front circumferential slot portions 14e-1, the cam ring 11 is not given any force making the cam ring 11 move forward. Consequently, the cam ring 11 only rotates at an axial fixed position in accordance with rotation of the third external barrel 15.

【0020】

Rotating the zoom gear 28 in a lens barrel retracting direction thereof causes the aforementioned movable elements of the zoom lens 71 from the stationary barrel 22 to the cam ring 11 to operate in the reverse

manner to the above described advancing operations. In this reverse operation, the above described fundamental movable elements of the zoom lens 71 retract to their respective retracted positions shown in Figure 7 by rotation of the helicoid ring 18 until the set of three followers 32 enter the rear circumferential slot portions 14e-2 of the set of three guide lots 14e, respectively.

【0021】

The first linear guide ring 14 is provided on an inner peripheral surface thereof with a set of three pairs of first linear guide grooves 14f which are formed at different circumferential positions to extend parallel to the photographing optical axis Z1, and a set of six second linear guide grooves 14g which are formed at different circumferential positions to extend parallel to the photographing optical axis Z1. Each pair of first linear guide grooves 14f are position on the opposite sides of the associated linear guide groove 14g (every other linear guide groove 14g) in a circumferential direction of the first linear guide ring 14. A second linear guide ring 10 is provided on an outer edge thereof with a set of three bifurcated projections 10a. Each bifurcated projection 10a (see Figures 3 and 15) is provided at a radially outer end thereof with a

pair of radial projections which are respectively engaged in the associated pair of first linear guide grooves 14f. On the other hand, a set of six radial projections 13a (see Figures 2 and 17) which are formed on an outer peripheral surface of the second external barrel 13 at a rear end thereof to project radially outwards are engaged in the set of six second linear guide grooves 14g, respectively to be slidable therealong. Therefore, each of the second external barrel 13 and the second linear guide ring 10 is guided in the optical axis direction via the first linear guide ring 14.

【0022】

The second linear guide ring 10 serves as a linear guide member for guiding a second lens group moving frame 8 linearly without rotating the same, while the second external barrel 13 serves as a linear guide member for guiding the first external barrel 12 linearly without rotating the same. The second lens group moving frame 8 supports the second lens group LG2. The first external barrel 12 supports the first lens group LG1.

【0023】

The second linear guide ring 10 is provided on a ring portion 10b thereof with a set of three linear guide keys 10c which project forward (see Figures 3 and 15) from the ring portion 10b. As shown in Figures 6 and 7, an outer

edge of the ring portion 10b is engaged in a circumferential groove 11e formed on an inner peripheral surface of the cam ring 11 at the rear end thereof to be rotatable about the lens barrel axis Z0 relative to the cam ring 11 and to be immovable relative to the cam ring 11 in the optical axis direction. The set of three linear guide keys 10c project forward from the ring portion 10b to be positioned inside the cam ring 11. Opposite edges of each linear guide key 10c in a circumferential direction of the second linear guide ring 10 serve as parallel guide edges which are respectively engaged with circumferentially-opposed guide surfaces in an associated linear guide groove 8a of the second lens group moving frame 8, which is positioned in the cam ring 11 to be supported thereby, to guide the second lens group moving frame 8 linearly in the optical axis direction without rotating the same about the lens barrel axis Z0. The linear guide grooves 8a are formed on an outer peripheral surface of the second lens group moving frame 8.

【0024】

As shown in Figure 3, the cam ring 11 is provided on an inner peripheral surface thereof with a plurality of cam grooves 11a for guiding the second lens group LG2. A plurality of cam followers 8b which are provided on an

outer peripheral surface of the second lens group moving frame 8 are engaged in the plurality of cam grooves 11a. A rotation of the cam ring 11 causes the second lens group moving frame 8 to move in the optical axis direction in a predetermined moving manner in accordance with contours of the plurality of cam grooves 11a since the second lens group moving frame 8 is guided linearly in the optical axis direction without rotating via the second linear guide ring 10. A guide mechanism for guiding the second lens group moving frame 8 by the plurality of cam grooves 11a will be discussed in detail later.

【0025】

The zoom lens 71 is provided inside the second lens group moving frame 8 with a second lens frame 6. The second lens frame 6 is pivoted on a pivot shaft 33 front and rear ends of which are supported by front and rear second lens frame support plates 36 and 37, respectively. The pair of second lens frame support plates 36 and 37 are fixed to the second lens group moving frame 8 by a set screw 66. The pivot shaft 33 is a predetermined distance away from the photographing optical axis Z1, and extend parallel to the photographing optical axis Z1. The second lens frame 6 is swingable about the pivot shaft 33 between a photographing position shown in Figure 6

where the optical axis of the second lens group LG2 coincides with the photographing optical axis Z1 and a retracted position shown in Figure 7 where the optical axis of the second lens group LG2 is eccentric from the photographing optical axis Z1. A rotation limit shaft 35 which determines the photographing position of the second lens frame 6 is mounted to the second lens group moving frame 8. The second lens frame 6 is biased to rotate in a direction to come into contact with the rotation limit shaft 35 by a front torsion coil spring 39. A compression coil spring 38 removes backlash of the second lens frame 6 in the optical axis direction.

【0026】

The second lens frame 6 moves together with the second lens group moving frame 8 in the optical axis direction. The CCD holder 21 is provided on a front surface thereof with a position-control cam bar 21a which projects forward from the CCD holder 21to be engageable with the second lens frame 6 (see Figure 4). If the second lens group moving frame 8 moves rearward in a retracting direction to approach the CCD holder 21, a cam surface formed on a front end surface of the position-control cam bar 21a comes into contact with the second lens frame 6 to rotate the second lens frame 6 to the retracted position.

【0027】

The second external barrel 13 is provided, on an inner peripheral surface thereof for supporting the first lens group LG1, with a set of three linear guide grooves 13b which are formed at different circumferential positions to extend in the optical axis direction. The first external barrel 12 is provided on an outer peripheral surface thereof at the rear end of the first external barrel 12 with a set of three engaging protrusions 12a which are slidably engaged in the set of three linear guide grooves 13b, respectively (see Figures 2, 17 and 18). Accordingly, the first external barrel 12 is guided linearly in the optical axis direction without rotating about the lens barrel axis Z0 via the first linear guide ring 14 and the second external barrel 13. The second external barrel 13 is further provided on an inner peripheral surface thereof in the vicinity of the rear end of the second external barrel 13 with a inner flange 13c which extends along a circumference of the second external barrel 13. The cam ring 11 is provided on an outer peripheral surface thereof a circumferential groove 11c in which the inner flange 13c is slidably engaged so that the cam ring 11 is rotatable about the lens barrel axis Z0 relative to the second external barrel 13 and so that the second

external barrel 13 is immovable in the optical axis direction relative to the cam ring 11. On the other hand, the first external barrel 12 is provided on an inner peripheral surface thereof with a set of three rollers (cam followers) 31 which projects radially inwards, while the cam ring 11 is provided on an outer peripheral surface thereof with a set of three cam grooves 11b (for guiding the first lens group LG1) in which the set of three rollers 31 are slidably engaged, respectively.

【0028】

A first lens frame 1 is supported inside the first external barrel 12 by the first external barrel 12 via a first lens group adjustment ring 2. The first lens group LG1 is supported by the first lens frame 1 to be fixed thereto. The first lens frame 1 is provided on an outer peripheral surface thereof with a male screw thread 1a, and the first lens group adjustment ring 2 is provided on an inner peripheral surface thereof with a female screw thread 2a which is engaged with the male screw thread 1a. The axis position of the first lens frame 1 relative to the first lens group adjustment ring 2 can be adjusted via the male screw thread 1a and the female screw thread 2a.

【0029】

The inner flange 12c of the first external barrel

12 is provided at radially opposite positions thereon with respect to the photographing optical axis Z1 with a pair of first guide grooves 12b, respectively, while the first lens group adjustment ring 2 is provided on an outer peripheral surface thereof with a corresponding pair of guide projections 2b (only one of them appears in Figure 2) which project radially outwards in opposite directions away from each other to be slidably fitted in the pair of first guide grooves 12b, respectively. The pair of first guide grooves 12b extend parallel to the photographing optical axis Z1 so that the combination of the first lens frame 1 and the first lens group adjustment ring 2 is movable in the optical axis direction with respect to the first external barrel 12 by engagement of the pair of guide projections 2b with the pair of first guide grooves 12b. The fixing ring 3 is fixed to the first external barrel 12 by the two set screws 64 to close the front of the pair of guide projections 2b. The fixing ring 3 is provided at radially opposite positions thereon with respect to the photographing optical axis Z1 with a pair of spring receiving portions 3a so that a pair of compression coil springs 24 are installed in a compressed fashion between the pair of spring receiving portions 3a and the pair of guide projections 2b, respectively. Therefore, the first lens group

adjustment ring 2 is biased rearward in the optical axis direction with respect to the first external barrel 12 by the spring force of the pair of compression coil springs 24. The rear limit for the axial movement of the first lens group adjustment ring 2 with respect to the fixing ring 3 is determined by engagement of a set of four engaging projections 2c of the first lens group adjustment ring 2 with a front surface (which can be seen in Figure 2) of the fixing ring 3 (see an upper half of the zoom lens in Figure 6).

【0030】

The zoom lens 71 is provided between the first and second lens groups LG1 and LG2 with a shutter unit 76 including the shutter S and the adjustable diaphragm A. The shutter unit 76 is positioned in the second lens group moving frame 8 to be supported thereby. The aerial space between the shutter S and the second lens group LG2 is fixed. Likewise, the aerial space between the diaphragm A and the second lens group LG2 is fixed. The zoom lens 71 is provided in front of the shutter unit 76 with a shutter actuator (not shown) for driving the shutter S, and is provided behind the shutter unit 76 with a diaphragm actuator (not shown) for driving the diaphragm A. An exposure control FPC (flexible printed circuit) board 77 extends from the shutter unit 76 to establish

electrical connection between the control circuit and each of the shutter actuator and the diaphragm actuator.

【0031】

The zoom lens 71 is provided at the front end of the first external barrel 12 with a lens barrier mechanism which automatically closes a front end aperture of the zoom lens 71 when the zoom lens 71 is retracted into the camera body 72 to protect the frontmost lens element of the photographing optical system of the zoom lens 71, i.e. the first lens group LG1, from getting stains and scratches thereon when the digital camera 70 is not in use. The lens barrier mechanism is provided with a pair of barrier blades 104 and 105. The pair of barrier blades 104 and 105 are rotatable about two pivots projecting rearward therefrom to be positioned on radially opposite sides of the photographing optical axis Z1, respectively. The lens barrier mechanism is further provided with a pair of barrier blade biasing springs 106, a barrier blade drive ring 103, a drive ring biasing spring 107 and a barrier blade holding plate 102. The pair of barrier blades 104 and 105 are biased to rotate in opposite directions to be closed by the pair of barrier blade biasing springs 106, respectively. The barrier blade drive ring 103 is rotatable about the lens barrel axis Z0, and is engaged with the pair of barrier

blades 104 and 105 to open the pair of barrier blades 104 and 105 when driven to rotate in a predetermined rotational direction. The barrier blade drive ring 103 is biased to rotate in a barrier opening direction to open the pair of barrier blades 104 and 105 by the drive ring biasing spring 107. The barrier blade holding plate 102 is positioned between the barrier blade drive ring 103 and the pair of barrier blades 104 and 105. The spring force of the drive ring biasing spring 107 is greater than the spring force of the pair of barrier blade biasing springs 106 so that the barrier blade drive ring 103 is held in a specific rotational position thereof to open the pair of barrier blades 104 and 105 against the biasing force of the pair of barrier blade biasing springs 106 in the state shown in Figure 6 where the zoom lens 71 has been extended forward to a point in a zooming range (zooming operation performable range) where a zooming operation can be carried out. In the course of the retracting movement of the zoom lens 71 to the retracted position shown in Figure 10 from a position in the zooming range, the barrier blade drive ring 103 is forcefully rotated in a barrier closing direction opposite to the aforementioned barrier opening direction by a barrier drive ring pressing surface 11d (see Figures 3 and 13) formed on the cam ring 11. This rotation of the barrier

blade drive ring 103 causes the barrier blade drive ring 103 to be disengaged from the pair of barrier blades 104 and 105 so that the pair of barrier blades 104 and 105 are closed by the spring force of the pair of barrier blade biasing springs 106. The zoom lens 71 is provided immediately in front of the lens barrier mechanism with a lens barrier cover (decorative plate) 101 which covers the front of the lens barrier mechanism.

【0032】

A lens barrel advancing operation and a lens barrel retracting operation of the zoom lens 71 having the above described structure will be roughly discussed hereinafter. The stage at which the cam ring 11 is driven to advance from the retracted position to the position where the cam ring 11 rotates at the axial fixed position without moving in the optical axis direction has been discussed above, and will be briefly discussed hereinafter. In the state shown in Figure 7 in which the zoom lens 71 is in the retracted state, the zoom lens 71 is fully accommodated in the camera body 72 so that the front face of the zoom lens 71 is substantially flush with the front face of the camera body 72. Rotating the zoom gear 28 in the lens barrel advancing direction by the zoom motor 150 causes a combination of the helicoid ring 18 and the third external barrel 15 to move forward while

rotating about the lens barrel axis Z0 due to engagement of the female helicoid 22a with the male helicoid 18a, and further causes the first linear guide ring 14 to move forward together with the helicoid ring 18 and the third external barrel 15. At this time, the cam ring 11 which rotates by rotation of the third external barrel 15 moves forward in the optical axis direction by an amount of movement corresponding to the sum of the amount of the forward movement of the first linear guide ring 14 and the amount of the forward movement of the cam ring 11 by a leading structure between the cam ring 11 and the first linear guide ring 14 (by engagement of the set of three followers 32 with the lead slot portions 14e-3 of the set of three guide lots 14e, respectively). Once the combination of the helicoid ring 18 and the third external barrel 15 advances to a predetermined point, the male helicoid 18a is disengaged from the female helicoid 22a while the set of three followers 32 are disengaged from the lead slot portions 14e-3 to enter the front circumferential slot portions 14e-1, respectively. Consequently, each of the helicoid ring 18 and the third external barrel 15 rotates about the lens barrel axis Z0 without moving in the optical axis direction.

【0033】

A rotation of the cam ring 11 causes the second lens

group moving frame 8, which is positioned inside the cam ring 11, to move in the optical axis direction with respect to the cam ring 11 in a predetermined moving manner due to the engagement of the plurality of cam followers 8b with the plurality of cam grooves 11a, respectively. In the state shown in Figure 7 in which the zoom lens 71 is in the retracted state, the second lens frame 6, which is positioned inside the second lens group moving frame 8, has rotated about the pivot shaft 33 to be held in the retracted position above the photographing optical axis Z1 by the position-control cam bar 21a so that the optical axis of the second lens group LG2 moves from the photographing optical axis Z1 to a retracted optical axis Z2 positioned above the photographing optical axis Z1. In the course of movement of the second lens group moving frame 8 from the retracted position to a position in the zooming range, the second lens frame 6 is disengaged from the position-control cam bar 21a to rotate about the pivot shaft 33 from the retracted position to the photographing position shown in Figure 6 where the optical axis of the second lens group LG2 coincides with the photographing optical axis Z1 by the sprig force of the front torsion coil spring 39. Thereafter, the second lens frame 6 remains to be held in the photographing position until

when the zoom lens 71 is retracted into the camera body.

【0034】

In addition, a rotation of the cam ring 11 causes the first external barrel 12, which is positioned around the cam ring 11 and guided linearly in the optical axis direction without rotating, to move in the optical axis direction relative to the cam ring 11 in a predetermined moving manner due to engagement of the set of three rollers 31 with the set of three cam grooves 11b, respectively.

【0035】

Accordingly, an axial position of the first lens group LG1 relative to a picture plane (a light-sensitive surface of the CCD image sensor 60) when the first lens group LG1 is moved forward from the retracted position is determined by the sum of the amount of forward movement of the cam ring 11 relative to the stationary barrel 22 and the amount of movement of the first external barrel 12 relative to the cam ring 11, while an axial position of the second lens group LG2 relative to the picture plane when the second lens group LG2 is moved forward from the retracted position is determined by the sum of the amount of forward movement of the cam ring 11 relative to the stationary barrel 22 and the amount of movement of the second lens group moving frame 8 relative to the cam ring

11. A zooming operation is carried out by moving the first and second lens groups LG1 and LG2 on the photographing optical axis Z1 while changing the space therebetween. When the zoom lens 71 is driven to advance from the retracted position shown in Figure 7, the zoom lens 71 firstly goes into a state shown below the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at wide-angle extremity. Subsequently, the zoom lens 71 goes into the state shown above the photographing lens axis Z1 in Figure 9 in which the zoom lens 71 is set at telephoto extremity by a further rotation of the zoom motor 150 in a lens barrel advancing direction thereof. As can be seen from Figure 9, the space between the first and second lens groups LG1 and LG2 when the zoom lens 71 is set at the wide-angle extremity is greater than that when the zoom lens 71 is set at the telephoto extremity. When the zoom lens 71 is set at the telephoto extremity as shown above the photographing lens axis Z1 in Figure 9, the first and second lens groups LG1 and LG2 have moved to approach each other to have some space therebetween which is smaller than the space in the zoom lens 71 set at the wide-angle extremity. This variation of the space between the first and second lens groups LG1 and LG2 for zooming operation is achieved by contours of the plurality of cam

grooves 11a and the set of three cam grooves 11b. In the zooming range between the wide-angle extremity and the telephoto extremity, the cam ring 11, the third external barrel 15 and the helicoid ring 18 rotate at their respective axial fixed positions, i.e., without moving in the optical axis direction.

【0036】

In the zooming range, a focusing operation is carried out by moving the third lens group LG3 (the AF lens frame 51) along the photographing optical axis Z1 by rotation of the AF motor 160 in accordance with an object distance.

【0037】

Driving the zoom motor 150 in a lens barrel retracting direction causes the zoom lens 71 to operate in the reverse fashion to the above described advancing operation to fully retract the zoom lens 71 into the camera body 72 as shown in Figure 7. In the course of this retracting movement of the zoom lens 71, the second lens frame 6 rotates about the pivot shaft 33 to the retracted position by the position-control cam bar 21a while moving rearward together with the second lens group moving frame 8. When the zoom lens 71 is fully retracted into the camera body 72, the second lens group LG2 is retracted into the space radially outside the space in

which the third lens group LG3 and the low-pass filter LG4 are retracted as shown in Figure 10, i.e., the second lens group LG2 is into an axial range substantially identical to an axial range in the optical axis direction in which the third lens group LG3 and the low-pass filter LG4 are positioned. This structure of the camera 70 for retracting the second lens group LG2 in this manner reduces the length of the zoom lens 71 when the zoom lens 71 is fully retracted, thus making it possible to reduce the thickness of the camera body 72 in the horizontal direction as viewed in Figure 7.

【0038】

The digital camera 70 is provided with a zoom viewfinder the focal length of which varies to correspond to the focal length of the zoom lens 71. The zoom viewfinder is given a driving force from the helicoid ring 18 by engagement of a viewfinder drive gear 30 with the annular gear 18c of the helicoid ring 18 so that the viewfinder drive gear 30 rotates by rotation of the helicoid ring 18 when the helicoid ring 18 rotates at the aforementioned fixed position in the zooming range. The zoom viewfinder is provided with a zoom type viewing optical system including an objective window plate 81a, a first movable power-varyinglens 81b, a second movable power-varying lens 81c, a prism 81d, an eyepiece 81e and

a eyepiece window plate 81f in this order from the object side. The focal length of the zoom viewfinder varies by moving the first movable power-varying lens 81b and the second movable power-varying lens 81c along an optical axis Z3 of the objective optical system of the zoom viewfinder. The optical axis Z3 is parallel to the photographing optical axis Z1. Respective support frames of the first movable power-varying lens 81b and the second movable power-varying lens 81c are linearly guided in a direction of the optical axis Z3 by a guide shaft 82, and each receive a drive force from a screw shaft extending parallel to the guide shaft 82. The digital camera 70 is provided between this screw shaft and the viewfinder drive gear 30 with a reduction gear train. A rotation of the viewfinder drive gear 30 causes the screw shaft to rotate to thereby move the first movable power-varying lens 81b and the second movable power-varying lens 81c forward and rearward. The above described elements of the zoom viewfinder are put together to be prepared as a viewfinder unit (subassembly) 80 which is mounted on top of the stationary barrel 22.

【0039】

[DESCRIPTION OF FEATURES OF THE PRESENT INVENTION]

Features of the present invention will be

hereinafter discussed. In the above described zoom lens, the plurality of cam grooves 11a, which are formed on an inner peripheral surface of the cam ring 11, need reference cam diagrams α, shown in Figure 14, for giving a necessary movement to the second lens group moving frame (linear moving ring) 8. Each reference cam diagram α represents the shape of each cam groove of the set of three front cam grooves 11a-1 and the set of three rear cam grooves 11a-2, and includes a lens-barrel operating section and a lens-barrel assembling/disassembling section, wherein the lens-barrel operating section consists of a zooming section and a lens-barrel retracting section. The lens-barrel operating section serves as a control section which controls movement of the second lens group moving frame 8 with respect to the cam ring 11, and which is to be distinguished from the lens-barrel assembling/disassembling section. The zooming section serves as a control section which controls the movement of the second lens group moving frame 8 with respect to the cam ring 11, especially from a position of the second lens group moving frame 8 which corresponds to the wide-angle extremity of the zoom lens 71 to another position of the second lens group moving frame 8 which corresponds to the telephoto extremity of the zoom lens

71, and which is to be distinguished from the lens-barrel retracting section.

【0040】

As can be seen in Figure 27, a length of an axial range W1 of the reference cam diagrams α in the optical axis direction (the horizontal direction as viewed in Figure 27) is greater than a length W2 of the cam ring 11 in the optical axis direction. The length of the zooming section included in the axial range W1 of the reference cam diagrams α in the optical axis direction is represented by a length W3. This means that a set of cam grooves each having a sufficient length will not be obtained for the present embodiment of the cam ring 11 if designed according to a conventional method of formation of cam groove wherein a set of long cam grooves which entirely trace a corresponding set of long cam diagrams are formed on a peripheral surface of a cam ring. According to a cam mechanism of the present embodiment of the zoom lens, a sufficient range of movement of the second lens group moving frame 8 in the optical axis direction can be secured without increasing the length of the cam ring 11 in the optical axis direction. The detail of this cam mechanism will be discussed hereinafter.

【0041】

As shown in Figure 14, the plurality of cam grooves 11a are composed of a set of three front cam grooves 11a-1 formed at different circumferential positions, and a set of three rear cam grooves 11a-2 formed at different circumferential positions behind the set of three front cam grooves 11a-1. Although each front cam groove 11a-1 and each rear cam groove 11a-2 trace their respective reference cam diagrams α having the same shape, each front cam groove 11a-1 does not cover the entire range of the associated reference cam diagram α while each rear cam groove 11a-2 does not cover the entire range of the associated reference cam diagram α either. A range of each front cam groove 11a-1 which is included in the associated reference cam diagram α is partly different from a range of each rear cam groove 11a-2 which is included in the associated reference cam diagram α. Each reference cam diagram α can be roughly divided into four sections: first through fourth sections $\alpha 1$ through $\alpha 4$. The first section $\alpha 1$ extends in the optical axis direction. The second section $\alpha 2$ extends from a first inflection point αh positioned at the rear end of the first section $\alpha 1$ to a second inflection point αm positioned behind the first inflection point αh in the optical axis direction. The third section $\alpha 3$ extends from the second inflection point αm to a third inflection

point αn positioned in front of the second inflection point αm in the optical axis direction. The fourth section α4 extends from the third inflection point αn. The fourth section α4 is used only when the zoom lens 71 is assembled or disassembled, and is included in both each front cam groove 11a-1 and each rear cam groove 11a-2. Each front cam groove 11a-1 is formed in the vicinity of the front end of the cam ring 11 not to include the entire part of the first section α1 and a part of the second section α2, and is formed to include a front end opening R1 at an intermediate point of the second section α2 so that the front end opening R1 opens on a front end surface of the cam ring 11. On the other hand, each rear cam groove 11a-2 is formed in the vicinity of the rear end of the cam ring 11 not to include adjoining portions of the second section α2 and the third section α3 on opposite sides of the second inflection point αm. In addition, each rear cam groove 11a-2 is formed to include a front end opening R4 at the front end of the first section α1 so that the front end opening R4 opens on a front end surface of the cam ring 11. A missing part of each front cam groove 11a-1 which lies on the associated reference cam diagram α is included in the associated rear cam groove 11a-2 that is positioned behind the front cam groove 11a-1 in the optical axis

direction, whereas a missing part of each rear cam groove 11a-2 which lies on the associated reference cam diagram α is included in the associated front cam groove 11a-1 that is positioned in front of the rear cam groove 11a-2 in the optical axis direction. That is, if each front cam groove 11a-1 and the associated rear cam groove 11a-2 are combined into a single cam groove, this signal cam groove will include the entire part of one reference cam diagram α. The width of each front cam groove 11a-1 and the width of each rear cam groove 11a-2 are the same.

【0042】

Meanwhile, as shown in Figure 16, the plurality of cam followers 8b, which are respectively engaged in the plurality of cam grooves 11a, consist of the set of three front cam followers 8b-1 that are formed at different circumferential positions, and the set of three rear cam followers 8b-2 that are formed at different circumferential positions behind the set of three front cam followers 8b-1 in the optical axis direction, wherein each front cam follower 8b-1 and the rear cam follower 8b-2 positioned therebehind in the optical axis direction are provided as a pair in a manner similar to each pair of cam grooves 11a. The space between the set of three front cam followers 8b-1 and the set of three rear cam followers 8b-2 in the optical axis direction is

determined so that the set of three front cam followers 8b-1 are respectively engaged in the set of three front cam grooves 11a-1 and so that the set of three rear cam followers 8b-2 are respectively engaged in the set of three rear cam grooves 11a-2. The diameter of each front cam follower 8b-1 and the diameter of each rear cam follower 8b-2 are the same.

【0043】

Figure 19 shows the positional relationship between the plurality of cam grooves 11a and the plurality of cam followers 8b when the zoom lens 71 is the retracted state as shown in Figure 7. When the zoom lens 71 is the retracted state, each front cam follower 8b-1 is positioned in the associated front cam groove 11a-1 in the vicinity of the third inflection point αn thereof while each rear cam follower 8b-2 is positioned in the associated rear cam groove 11a-2 in the vicinity of the third inflection point αn thereof. Since each front cam groove 11a-1 includes a portion thereof in the vicinity of the third inflection point αn while each rear cam groove 11a-2 includes a portion thereof in the vicinity of the third inflection point αn, each front cam follower 8b-1 and each rear cam follower 8b-2 are engaged in the associated front cam groove 11a-1 and the associated rear cam groove 11a-2, respectively.

【0044】

Rotating the cam ring 11 in the lens barrel advancing direction (upwards as viewed in Figure 19) in the retracted state shown in Figure 19 causes each front cam follower 8b-1 and each rear cam follower 8b-2 to be guided rearward in the optical axis direction to move on the third section $\alpha 3$ toward the second inflection point αm by the associated front cam groove 11a-1 and the associated rear cam groove 11a-2, respectively. In the middle of this movement of each cam follower 8b, each rear cam follower 8b-2 is disengaged from the associated rear cam groove 11a-2 through a rear end opening R3 thereof which opens on a rear end surface of the cam ring 11 because each rear cam groove 11a-2 does not include adjoining portions of the second section $\alpha 2$ and the third section $\alpha 3$ on opposite sides of the second inflection point αm. At this time, each front cam follower 8b-1 remains engaged in the associated front cam groove 11a-1 since each front cam groove 11a-1 includes a rear portion thereof in the optical axis direction which corresponds to the missing rear portion of each rear cam groove 11a-2 in the optical axis direction. On or after each rear cam follower 8b-2 being disengaged from the associated rear cam groove 11a-2 through the rear end opening R3 thereof, the second lens group moving frame 8 moves in the optical

axis direction by rotation of the cam ring 11 only due to engagement of each front cam follower 8b-1 with the associated front cam groove 11a-1.

【0045】

Figure 20 shows the positional relationship between the plurality of cam grooves 11a and the plurality of cam followers 8b when the zoom lens 71 is in the state shown below the photographing lens axis Z1 in Figure 6 in which the zoom lens 71 is set at the wide-angle extremity. In this state shown below the photographing lens axis Z1 in Figure 6, each front cam follower 8b-1 is positioned in the second section $\alpha 2$ slightly beyond the second inflection point αm. Although each rear cam follower 8b-2 is currently disengaged from the associated rear cam groove 11a-2 through the rear end opening R3 thereof as described above, each rear cam follower 8b-2 remains positioned on the associated reference cam diagram α because the associated front cam follower 8b-1 positioned in front of the rear cam follower 8b-2 remains engaged in the associated front cam groove 11a-1.

【0046】

Rotating the cam ring 11 in the lens barrel advancing direction (upward as viewed in Figure 20) in the state shown in Figure 20, in which the zoom lens 71 is set at the wide-angle extremity, causes each front cam

follower 8b-1 to be guided forward in the optical axis direction to move on the second section $\alpha 2$ toward the first section $\alpha 1$ by the associated front cam groove 11a-1. With this forward movement of each front cam follower 8b-1, each rear cam follower 8b-2 which is currently disengaged from the associated rear cam groove 11a-2 moves on the second section $\alpha 2$, and shortly enters a rear end opening R2 formed on a rear end surface of the cam ring 11 to be re-engaged in the associated rear cam groove 11a-2. On or after this re-engagement of each rear cam follower 8b-2 with the associated rear cam groove 11a-2, each front cam follower 8b-1 and each rear cam follower 8b-2 are guided by the associated front cam groove 11a-1 and the associated rear cam groove 11a-2, respectively. However, a shortly after the re-engagement of each rear cam follower 8b-2 with the associated rear cam groove 11a-2, each front cam follower 8b-1 is disengaged from the associated front cam groove 11a-1 through the front end opening R1 because a front end portion of each front cam groove 11a-1 which lies on the associated reference cam diagram α is missing. At this time, each rear cam follower 8b-2 remains engaged in the associated rear cam groove 11a-2 since each rear cam groove 11a-2 includes a front end portion thereof in the optical axis direction which corresponds to the

missing front end portion of each front cam groove 11a-1 in the optical axis direction. On or after each front cam follower 8b-1 being disengaged from the associated front cam groove 11a-1 through the front end opening R1 thereof, the second lens group moving frame 8 moves in the optical axis direction by rotation of the cam ring 11 only due to engagement of each rear cam follower 8b-2 with the associated rear cam groove 11a-2.

【0047】

Figure 21 shows the positional relationship between the plurality of cam grooves 11a and the plurality of cam followers 8b when the zoom lens 71 is in the state shown above the photographing lens axis Z1 in Figure 6 in which the zoom lens 71 is set at the telephoto extremity. In this state shown above the photographing lens axis Z1 in Figure 6, each front cam follower 8b-1 is positioned in the second section $\alpha 2$ in the vicinity of the first inflection point αh. Although each front cam follower 8b-1 is currently disengaged from the associated front cam groove 11a-1 through the front end opening R1 thereof as described above, each front cam follower 8b-1 remains on the associated reference cam diagram α because the associated rear cam follower 8b-2 positioned behind the front cam follower 8b-1 remains engaged in the associated rear cam groove 11a-2.

【0048】

Further rotating the cam ring 11 in the lens barrel advancing direction in the state shown in Figure 21, in which the zoom lens 71 is set at the telephoto extremity, causes each rear cam follower 8b-2 to enter the first section $\alpha 1$ via the first inflection point αh as shown in Figure 22. At this time, each front cam follower 8b-1 has been disengaged from the associated front cam groove 11a-1, and merely each rear cam follower 8b-2 is engaged in a front end portion (the first section $\alpha 1$) of the associated rear cam groove 11a-2 which extends in the optical axis direction, so that the second lens group moving frame 8 can be removed from the cam ring 11 from the front thereof in the optical axis direction to remove each rear cam follower 8b-2 from the associated rear cam groove 11a-2 via the front end opening R4. Accordingly, Figure 22 shows a state where the cam ring 11 and the second lens group moving frame 8 are put together or removed from each other.

【0049】

Figures 23 through 26 show the relationship between the cam ring 11 and the second lens group moving frame 8 in the retracted state, the wide-angle extremity state, the telephoto extremity state and the disassembled state, respectively, wherein the reference cam diagram

α are not illustrated while the second linear guide ring 10 is additionally illustrated in the drawings.

【0050】

As described above, each pair of cam grooves having the same reference cam diagram, i.e., each front cam groove 11a-1 and the associated rear cam groove 11a-2 are formed at different points in the optical axis direction on the cam ring 11; moreover, each front cam groove 11a-1 and the associated rear cam groove 11a-2 are formed so that one end of the front cam groove 11a-1 opens on a front end surface of the cam ring 11 without the front cam groove 11a-1 including the entire part of the associated reference cam diagram α and so that one end of the rear cam groove 11a-2 opens on a rear end surface of the cam ring 11 without the rear cam groove 11a-2 including the entire part of the associated reference cam diagram α ; and furthermore, one of the front cam groove 11a-1 and the rear cam groove 11a-2 is complemented by the other to include the entire part of one reference cam diagram α. In addition, only each rear cam follower 8b-2 is engaged in the associated rear cam groove 11a-2 when the second lens group moving frame 8 is positioned at a front limit for the axial movement thereof with respect to the cam ring 11 (which corresponds to the state shown above the photographing lens axis Z1 in Figure 6 in which the

zoom lens 71 is set at the telephoto extremity), while only each front cam follower 8b-1 is engaged in the associated front cam groove 11a-1 when the second lens group moving frame 8 is positioned at a rear limit for the axial movement thereof with respect to the cam ring 11 (which corresponds to a state shown below the photographing lens axis Z1 in Figure 6 in which the zoom lens 71 is set at the wide-angle extremity). With this structure, a sufficient range of movement of the second lens group moving frame 8 in the optical axis direction which is greater than the range of movement of the cam ring 11 in the optical axis direction is achieved. Namely, the length of the cam ring 11 in the optical axis direction can be reduced without sacrificing the range of movement of the second lens group moving frame 8, which supports the second lens group LG2, in the optical axis direction.

【0051】

The present embodiment of the barrel-advancing cam mechanism including the cam ring 11 has the following feature. In general, the amount of movement of each cam follower per unit of rotation of the cam ring decreases to thereby make it possible to move the driven member with a higher degree of positioning accuracy by rotation of the cam ring as the degree of inclination of each cam

groove on the cam ring relative to the rotational direction of the cam ring becomes small, i.e., as the direction of extension of each cam groove becomes close to a circumferential direction of the cam ring. In addition, the degree of resistance to the cam ring when it rotates becomes smaller to thereby make the driving torque for rotating the cam ring smaller as the degree of inclination of each cam groove on the cam ring relative to the rotational direction of the cam ring becomes small. A reduction of the driving torque results in an increase in durability of elements of the cam mechanism and a decrease in power consumption of the motor for driving the cam ring, and makes it possible to adopt a small motor for driving the cam ring to downsize the lens barrel. Although it is known that the actual contours of the cam grooves are determined in consideration of various factors such as the effective area of an outer or inner peripheral surface of the cam ring and the maximum angle of rotation of the cam ring, it is generally the case that there are the above described tendencies as for the cam grooves.

【0052】

It can be said that the cam ring 11 is provided, at regular intervals in a circumferential direction of the cam ring 11, with three pairs of cam grooves 11a for

guiding the second lens group LG2 if each front cam groove 11a-1 and the rear cam groove 11a-2 positioned therebehind in the optical axis direction are regarded as a pair. As for the reference cam diagrams α of the plurality of cam grooves 11a, provided only three of the reference cam diagrams α are to be arranged on an inner peripheral surface of the cam ring 11 along a line thereon extending in a circumferential direction of the cam ring 11, the three reference cam diagrams α will not interfere with one another on the inner peripheral surface of the cam ring 11 though each reference cam diagram α has an undulating shape. However, in the present embodiment of the zoom lens, in order to shorten the length of the cam ring 11 in the optical axis direction to thereby minimize the length of the zoom lens 71, six reference cam diagrams α need to be arranged on the inner peripheral surface of the cam ring 11 in total because the set of three front cam grooves 11a-1 and the corresponding set of three rear cam grooves (three discontinuous rear cam grooves) 11a-2, six cam grooves in total, need to be formed separately on front and rear portions on the inner peripheral surface of the cam ring 11 in the optical axis direction, respectively. Although each of the six cam grooves 11a-1 and 11a-2 is shorter than the reference cam diagram α, it is generally the case that the space for

the cam grooves 11a-1 and 11a-2 on the cam ring 11 becomes tighter as the number of the cam grooves is great. Therefore, if the number of the cam grooves is great, it is difficult to form the cam grooves on the cam ring without making the cam grooves interfering with each other. To prevent this problem from occurring, it has been conventionally practiced to increase the degree of inclination of each cam groove relative to the rotational direction of the cam ring (i.e., to make the direction of extension of each cam groove close to a circumferential direction of the cam ring) or to increase the diameter of the cam ring to enlarge the area of a peripheral surface of the cam ring on which the cam grooves are formed. However, the former is not preferable in terms of the attainment of a high degree of positioning accuracy in driving a driven member driven by the cam ring and also a saving in the driving torque for rotating the cam ring, and the latter is not preferable either because the zoom lens will be upsized.

【0053】

In contrast to such conventional practices, according to the present embodiment of the zoom lens, the inventor of the present invention has found the fact that a substantial performance characteristics of the cam mechanism is maintained even if each front cam groove

11a-1 intersects one of the set of three rear cam grooves 11a-2, as long as the reference cam diagrams α of the six cam grooves 11a (11a-1 and 11a-2) are the same while one cam follower of each pair of cam followers (each front cam follower 8b-1 and the associated rear cam follower 8b-2) remains engaged in the associated cam groove 11a-1 or 11a-2 at the moment at which the other cam follower 8b-1 or 8b-2 passes through a point of intersection between the front cam groove 11a-1 and the rear cam groove 11a-2. On the basis of this fact, each front cam groove 11a-1 and adjacent one of the set of three rear cam grooves 11a-2, which are adjacent to each other in a circumferential direction of the cam ring 11, are formed to intersect each other intentionally without changing the shape of each reference cam diagram α and without increasing the diameter of the cam ring 11. More specifically, if the three pairs of cam grooves 11a are respectively treated as a first pair of cam grooves G1, a second pair of cam grooves G2 and a third pair of cam grooves G3 as shown in Figure 14, the front cam groove 11a-1 of the first pair G1 and the rear cam groove 11a-2 of the second pair G2, which are adjacent to each other in a circumferential direction of the cam ring 11, intersect each other, the first cam groove 11a-1 of the second pair G2 and the rear cam groove 11a-2 of the third

pair G3, which are adjacent to each other in a circumferential direction of the cam ring 11, intersect each other, and the front cam groove 11a-1 of the third pair G3 and the rear cam groove 11a-2 of the first pair G1, which are adjacent to each other in a circumferential direction of the cam ring 11, intersect each other.

【0054】

To make one cam follower of each pair of cam followers remain properly engaged in the associated cam groove 11a-1 or 11a-2 at the moment at which the other cam follower passes through the point of intersection between the front cam groove 11a-1 and the rear cam groove 11a-2, the front cam groove 11a-1 and the rear cam groove 11a-2 of each pair of the first through third pairs of cam grooves G1, G2 and G3 are formed not only at different axial positions in the optical axis direction but also at different circumferential positions in a circumferential direction of the cam ring 11. The positional difference in a circumferential direction of the cam ring 11 between the front cam groove 11a-1 and the rear cam groove 11a-2 of each pair of the first through third pairs of cam grooves G1, G2 and G3 is indicated by " β " in Figure 14. This positional difference β changes the point of intersection between the front cam groove 11a-1 and the rear cam groove 11a-2

in a circumferential direction of the cam ring 11. Consequently, in each pair of the first through third pairs of cam grooves G1, G2 and G3, the point of intersection is positioned in the vicinity of the second inflection point αm on the third section α3 of the front cam groove 11a-1, and also in the vicinity of the front end opening R4 (in the vicinity of the first inflection point αh) at the front end of the first section α1.

【0055】

As can be understood from the above descriptions, at the moment at which the set of three front cam followers 8b-1 pass through the points of intersection in the set of three front cam grooves 11a-1, the set of three rear cam followers 8b-2 remain engaged in the set of three rear cam grooves 11a-2 so that the set of three front cam followers 8b-1 can pass through the points of intersection without being disengaged from the set of three front cam grooves 11a-1, respectively (see Figure 28), by forming the set of three front cam grooves 11a-1 and the corresponding set of three rear cam grooves 11a-2 in the above described manner. Although each front cam groove 11a-1 has the point of intersection therein between the zooming section and the lens-barrel retracting section, i.e. in the lens-barrel operating section, the lens barrel 71 can surely be advanced and

retracted with the cam ring 11 regardless of the existence of a section of each front cam groove 11a-1 which includes the point of intersection therein. Although each front cam follower 8b-1 is already disengaged from the associated front cam groove 11a-1 when each rear cam follower 8b-2 reaches the point of intersection in the rear cam groove 11a-2 as shown in Figures 21 and 25, this point of intersection is positioned in the lens-barrel assembling/disassembling section, i.e., out of the lens-barrel operating section, so that each rear cam follower 8b-2 is not in a state where it receives a torque from the cam ring 11. Accordingly, as for the set of three rear cam grooves 11a-2, a possibility of each rear cam follower 8b-2 being disengaged from the associated rear cam groove 11a-2 at the point of intersection therein does not have to be taken into consideration when the zoom lens 71 is in the ready-to-photograph state.

【0056】

The point of intersection in each front cam groove 11a-1 is in a section thereof through which the associated front cam follower 8b-1 passes between the retracted state of the zoom lens and the wide-angle extremity state of the zoom lens, while the point of intersection in each rear cam groove 11a-2 is in the

lens-barrel assembling/disassembling section as described above. Therefore, either each front cam groove 11a-1 or each rear cam groove 11a-2 does not have the point of intersection therein in the zooming range between the wide-angle extremity and the telephoto extremity. This makes it possible to insure a high degree of positioning accuracy in driving the second lens group LG2 during a zooming operation of the zoom lens 71 regardless of the existence of the point of intersection between cam grooves.

【0057】

Namely, the timing of engagement or disengagement of each cam follower in or from the associated cam groove can be varied by adjusting the positional difference in a circumferential direction of the cam ring 11 between the front and rear cam grooves 11a-1 and 11a-2, the reference cam diagrams α of which are the same. Moreover, the point of intersection between two cam grooves (11a-1 and 11a-2) can be positioned in an appropriate section therein which does not affect any adverse effect on a zooming operation by adjusting the aforementioned positional difference.

【0058】

As can be understood from the above descriptions, in the present embodiment of the zoom lens, each front

cam groove 11a-1 and each rear cam groove 11a-2 are successfully arranged on the inner peripheral surface of the cam ring 11 in a space-saving fashion without deteriorating the positioning accuracy in driving the second lens group LG2 by making each front cam groove 11a-1 and adjacent one of the set of three rear cam grooves 11a-2, which are adjacent to each other in a circumferential direction of the cam ring 11, intersect each other intentionally and further by forming each front cam groove 11a-1 and the associated rear cam groove 11a-2 not only at different axial positions in the optical axis direction but also at different circumferential positions in a circumferential direction of the cam ring 11. Accordingly, not only the length of the cam ring 11 in the optical axis direction but also the diameter of the cam ring 11 can be reduced.

【0059】

Although the plurality of cam grooves 11a (the set of three front cam grooves 11a-1 and the set of three rear cam grooves 11a-2) are provided as three groups of cam grooves which are formed at different circumferential positions in a circumferential direction of the cam ring while the plurality of cam followers 8b (the set of three front cam followers 8b-1 and the set of set of three rear cam followers 8b-2) are also provided as three groups of

cam followers which are formed at different circumferential positions in a circumferential direction of the second lens group moving frame 8 in the above illustrated embodiment, the number of groups of cam grooves formed on the cam ring 11 and the corresponding number of groups of cam followers formed on the second lens group moving frame 8 are optional.

【0060】

Although the number of cam grooves (11a-1 and 11a-2) included in each group of the three groups of cam grooves and formed at different positions along a rotational axis of the cam ring 11 is two while the number of cam followers (8b-1 and 8b-2) included in each group of the three groups of cam followers and formed at different positions along the rotational axis of the cam ring 11 is also two in the above illustrated embodiment, each of the former number and the latter number can be more than three. In the case where each of the former number and the latter number is more than three, not only each of the front and rear cam grooves is formed not to include a part of the entire portion of the associated reference cam diagram but also the middle cam groove is formed not to include a part of the entire portion of the associated reference cam diagram.

【0061】

Although each front cam groove 11a-1 is formed as a short cam groove excluding a front part of the entire portion of the associated reference cam diagram α while each rear cam groove 11a-2 is formed as a short cam groove excluding a rear part of the entire portion of the associated reference cam diagram α, the position of each end opening of either of the cam grooves 11a-1 and 11a-2 is optional. For instance, each rear cam groove 11a-2 does not need to be provided with the front end opening G4 if the cam ring does not have to be made in consideration of the workability of assembling and disassembling the zoom lens 71.

【0062】

Although the above illustrated embodiment relates to a zoom lens, the present invention can also be applied to various barrel-advancing cam mechanisms of any technical fields other than the technical field of the zoom lenses.

【0063】

【Effects of the Invention】

As can be understood from the foregoing, according to the barrel-advancing cam mechanism to which the present invention is applied, a cam ring can be miniaturized while the necessary moving amounts for movable lens groups and any other linearly moving

elements can be secured.

【BRIEF DESCRIPTION OF THE DRAWING】

Figure 1 is an exploded perspective view of an embodiment of a zoom lens having a barrel-advancing cam mechanism according to the present invention;

Figure 2 is an exploded perspective view of a structure supporting a first lens group of the zoom lens;

Figure 3 is an exploded perspective view of a structure supporting a second lens group of the zoom lens;

Figure 4 is an exploded perspective view of a barrel-advancing structure from a stationary barrel to a cam ring;

Figure 5 is a perspective view of the zoom lens shown in Figure 1, showing a completed state thereof to which a zoom motor and a viewfinder unit are fixed;

Figure 6 is a longitudinal cross sectional view of a camera incorporating the zoom lens shown in Figure 1, showing a state of the zoom lens at telephoto extremity and a state of the zoom lens at wide-angle extremity;

Figure 7 is a longitudinal cross sectional view of the camera shown in Figure 6 in the retracted state of the zoom lens;

Figure 8 is a plan view of the stationary barrel;

Figure 9 is a plan view of a helicoid ring;

Figure 10 is a plan view of the helicoid ring, showing a structure of the inner peripheral surface thereof by broken lines;

Figure 11 is a plan view of a third external barrel;

Figure 12 is a plan view of a linear guide ring;

Figure 13 is a plan view of the cam ring;

Figure 14 is a plan view of the cam ring, showing a structure of the inner peripheral surface thereof by broken lines;

Figure 15 is a plan view of a second linear guide ring;

Figure 16 is a plan view of a second lens group moving frame;

Figure 17 is a plan view of a second external barrel;

Figure 18 is a plan view of a first external barrel;

Figure 19 is a plan view of the cam ring and the second lens group moving frame, showing the relationship therebetween in the retracted state of the zoom lens;

Figure 20 is a plan view of the cam ring and the second lens group moving frame, showing the relationship therebetween at the wide-angle extremity of the zoom lens;

Figure 21 is a plan view of the cam ring and the second lens group moving frame, showing the relationship therebetween at the telephoto extremity of the zoom lens;

Figure 22 is a plan view of the cam ring and the second lens group moving frame, showing the relationship therebetween in a state where the zoom lens can be disassembled;

Figure 23 is a plan view of the cam ring, the second lens group moving frame and the second linear guide ring, showing the relationship thereamong in the retracted state of the zoom lens;

Figure 24 is a plan view of the cam ring, the second lens group moving frame and the second linear guide ring, showing the relationship thereamong at the wide-angle extremity of the zoom lens;

Figure 25 is a plan view of the cam ring, the second lens group moving frame and the second linear guide ring, showing the relationship thereamong at the telephoto extremity of the zoom lens;

Figure 26 is a plan view of the cam ring, the second lens group moving frame and the second linear guide ring, showing the relationship thereamong in a state where the zoom lens can be disassembled;

Figure 27 is a plan view of the cam ring, showing the positions of cam followers for the second lens group in cam grooves for guiding the second lens group when the zoom lens is in the retracted position, the wide-angle extremity position and the telephoto extremity position;

and

Figure 28 is plan view of the cam ring, showing a state where a set of front cam followers pass through the points of intersection between a set of front cam grooves and a set of rear cam grooves of the cam ring.

【DESCRIPTIONS OF THE NUMERALS】

α reference cam diagrams of cam grooves for guiding the second lens group

β positional difference in a circumferential direction of a cam ring between front cam groove and rear cam groove of the cam grooves for guiding the second lens group

LG1 first lens group

LG2 second lens group

LG3 third lens group

LG4 fourth lens group

S shutter

A diaphragm

Z0 lens barrel axis

Z1 photographing optical axis

Z2 optical axis of the second lens group

Z3 optical axis of an objective optical system of a viewfinder

1 first lens frame

6 second lens frame

8 second lens group moving frame (linearly movable

ring)

8a linear guide groove

8b cam followers for the second lens group (cam follower group)

8b-1 front cam followers

8b-2 rear cam followers

10 second linear guide ring

10a bifurcated projections

10b ring portion

10c linear guide keys

11 cam ring

11a cam grooves for guiding the second lens group (cam groove group)

11a-1 front cam grooves

11a-2 rear cam grooves

11b cam grooves for guiding the first lens group

11c circumferential groove

12 first external barrel

13 second external barrel

14 linear guide ring

15 third external barrel

17 roller-biasing spring

18 helicoid ring

21 CCD holder

22 stationary barrel

28 zoom gear

31 rollers for the first lens group

32 followers of the cam ring

33 pivot shaft for the second lens group

51 AF lens frame

60 solid-state image pick-up device (CCD)

70 digital camera

71 zoom lens

72 camera body

76 shutter unit

80 viewfinder unit

150 zoom motor

160 AF motor

【TITLE OF THE DOCUMENT】 ABSTRACT

【ABSTRACT】

【OBJECTIVE】

It is an object of the present invention to provide a barrel-advancing cam mechanism, having a cam ring and used in a zoom lens, wherein the cam ring is miniaturized without sacrificing the range of movement of one or more movable lens group.

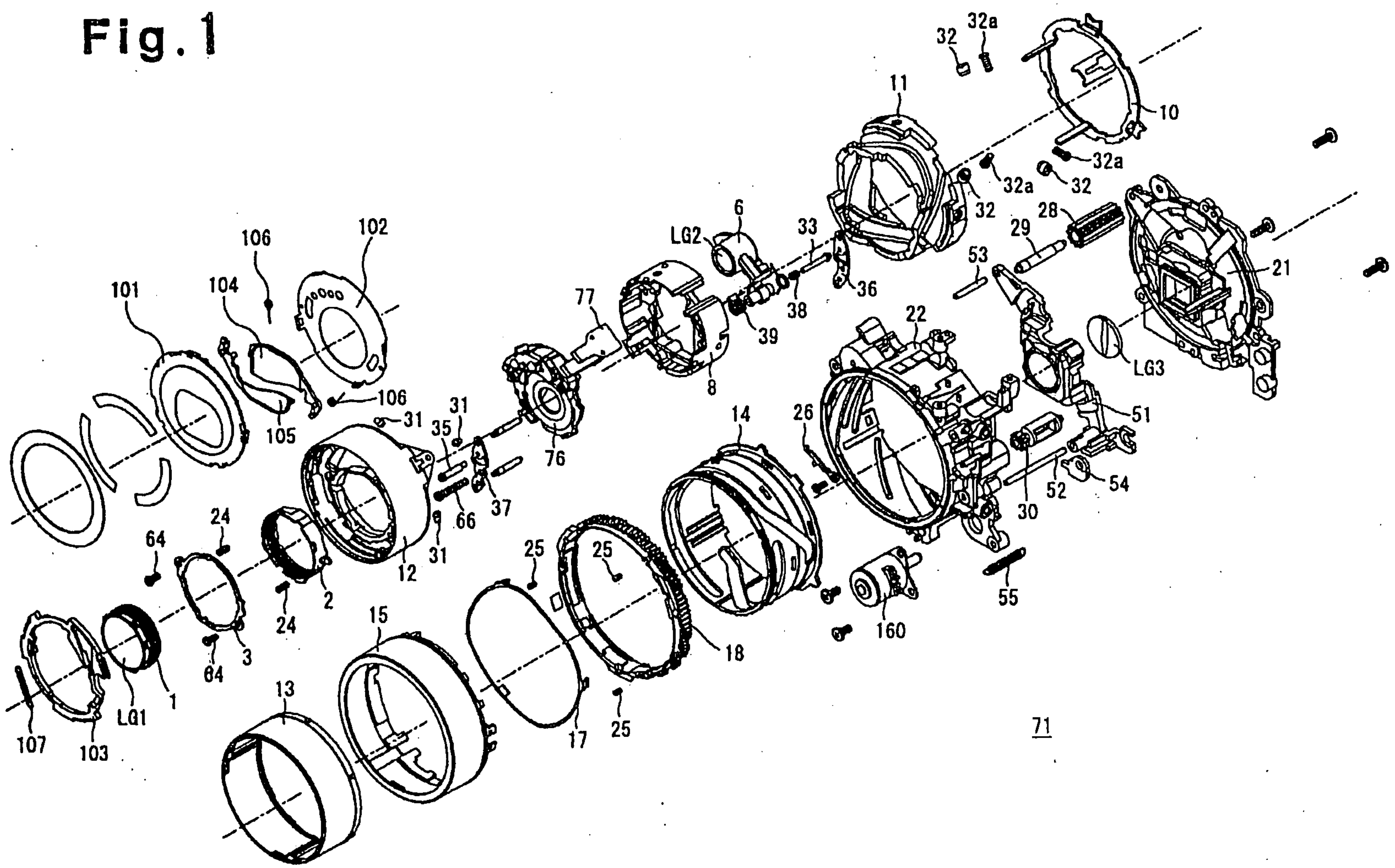
【CONSTITUTION】

A barrel-advancing cam mechanism of a zoom lens which includes: a cam ring having a plurality of cam grooves formed at different positions at least in the optical axis direction and which trace substantially a same reference cam diagram, wherein all cam grooves of the plurality of cam grooves are partial cam grooves each having at least one end opening at at least one of opposite ends of the cam ring so as not to include an entire portion of the reference cam diagram. The plurality of cam followers are formed on a linearly movable ring at different positions at least in the optical axis direction and are respectively engageable in the plurality of cam grooves. At least one of the plurality of cam followers remains engaged in a corresponding the cam groove while at least one of the other of the plurality of cam followers comes out of the

end opening and is disengaged therefrom, when the linearly movable ring moves to at least one of opposite limits for movement thereof in the optical axis direction.

【SELECTED FIGURE】 Figure 20

Fig. 1



32
32a
11
10
32a
32a
32
32
6
33
28
29
21
LG2
36
38
53
39
22
LG3
77
101
104
106
102
8
51
106
31
31
35
76
14
26
30
52
54
37
66
31
24
64
12
25
25
2
24
55
160
3
64
15
1
LG1
18
13
107
103
17
25
71

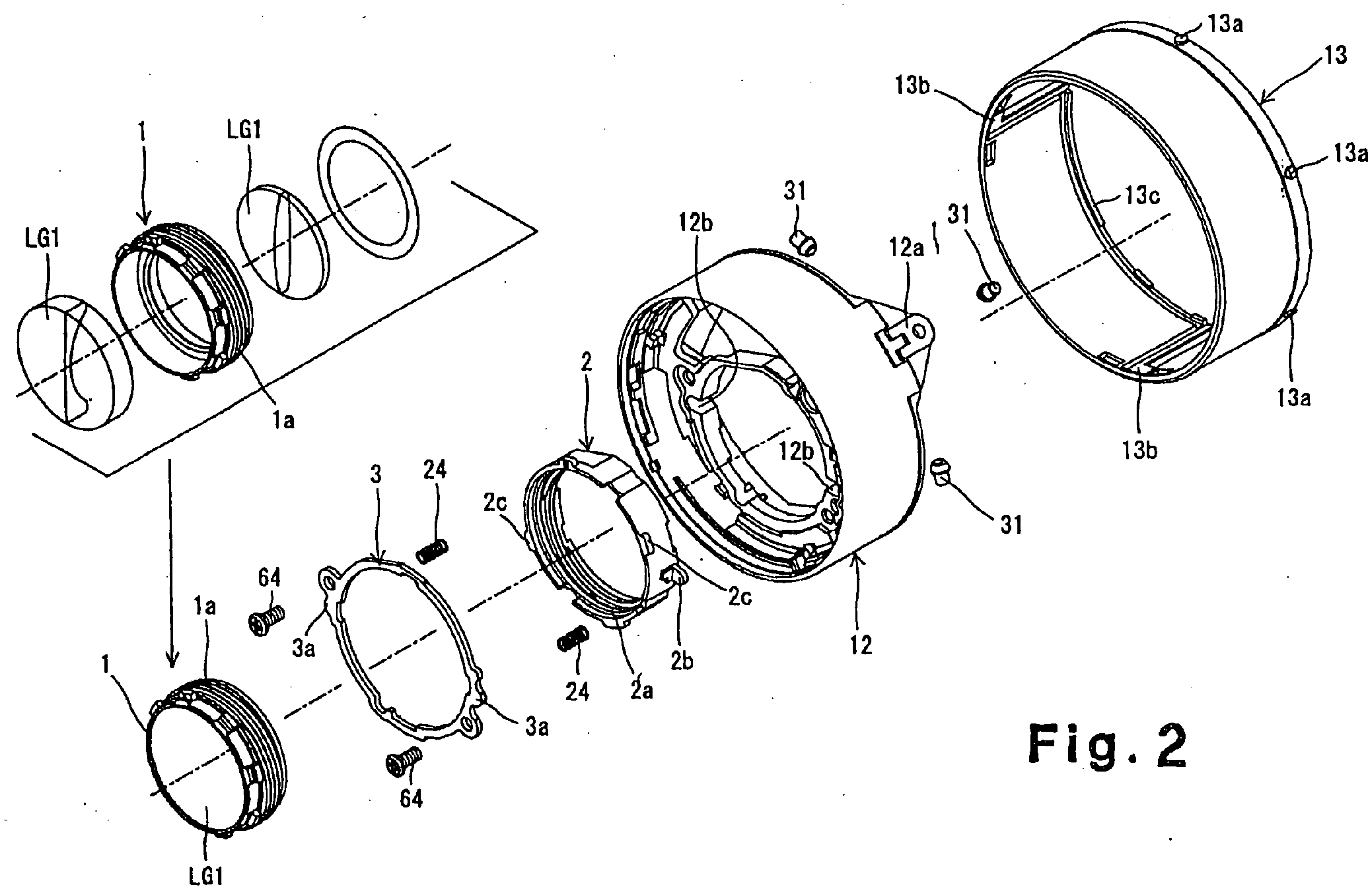

1
LG1
LG1
1a
1
1a
LG1
64
64
3
3a
3a
24
24
2
2c
2c
2a
2b
12b
12b
31
31
31
12a
12
13
13a
13a
13a
13b
13b
13c

Fig. 2

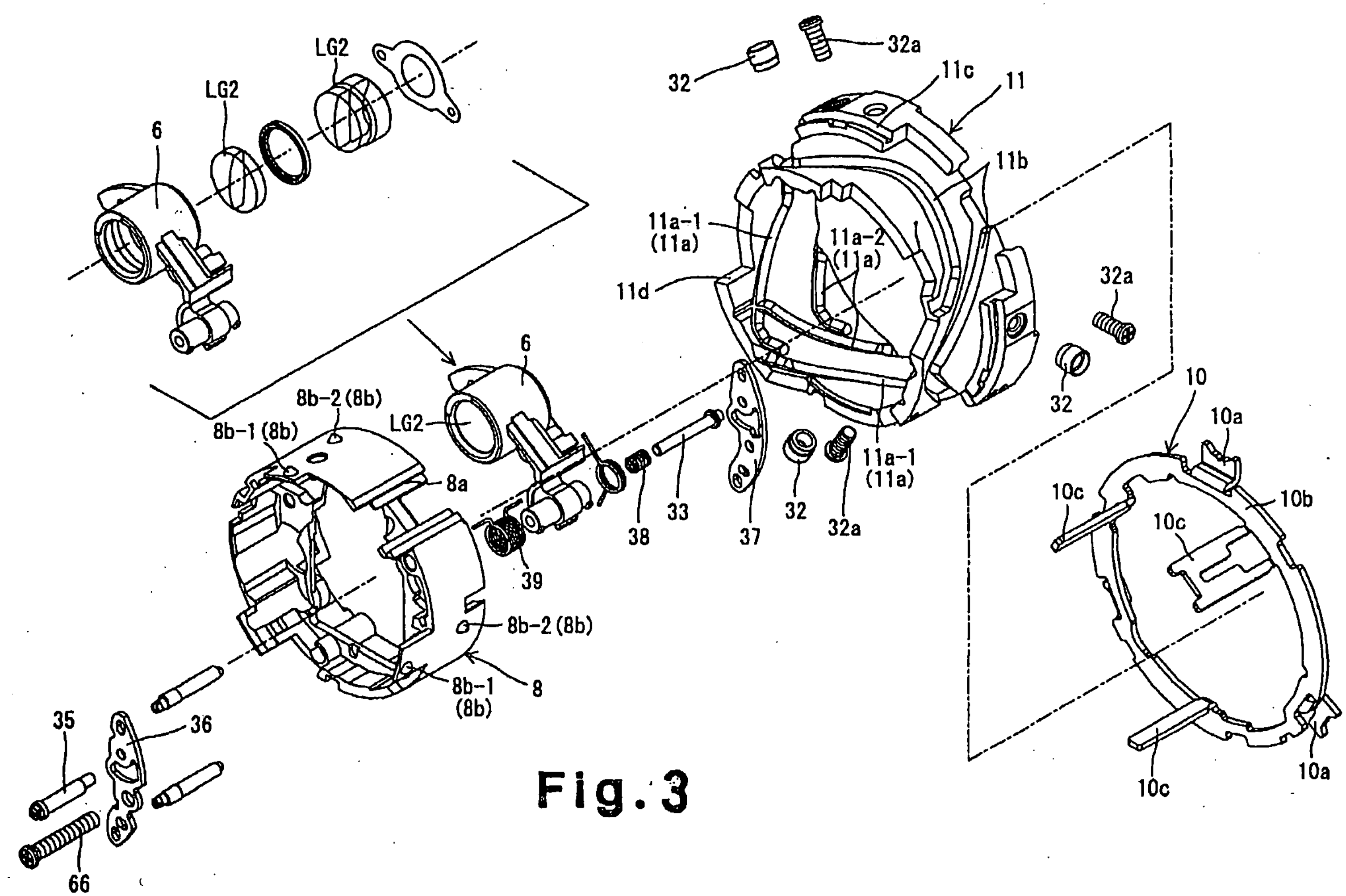
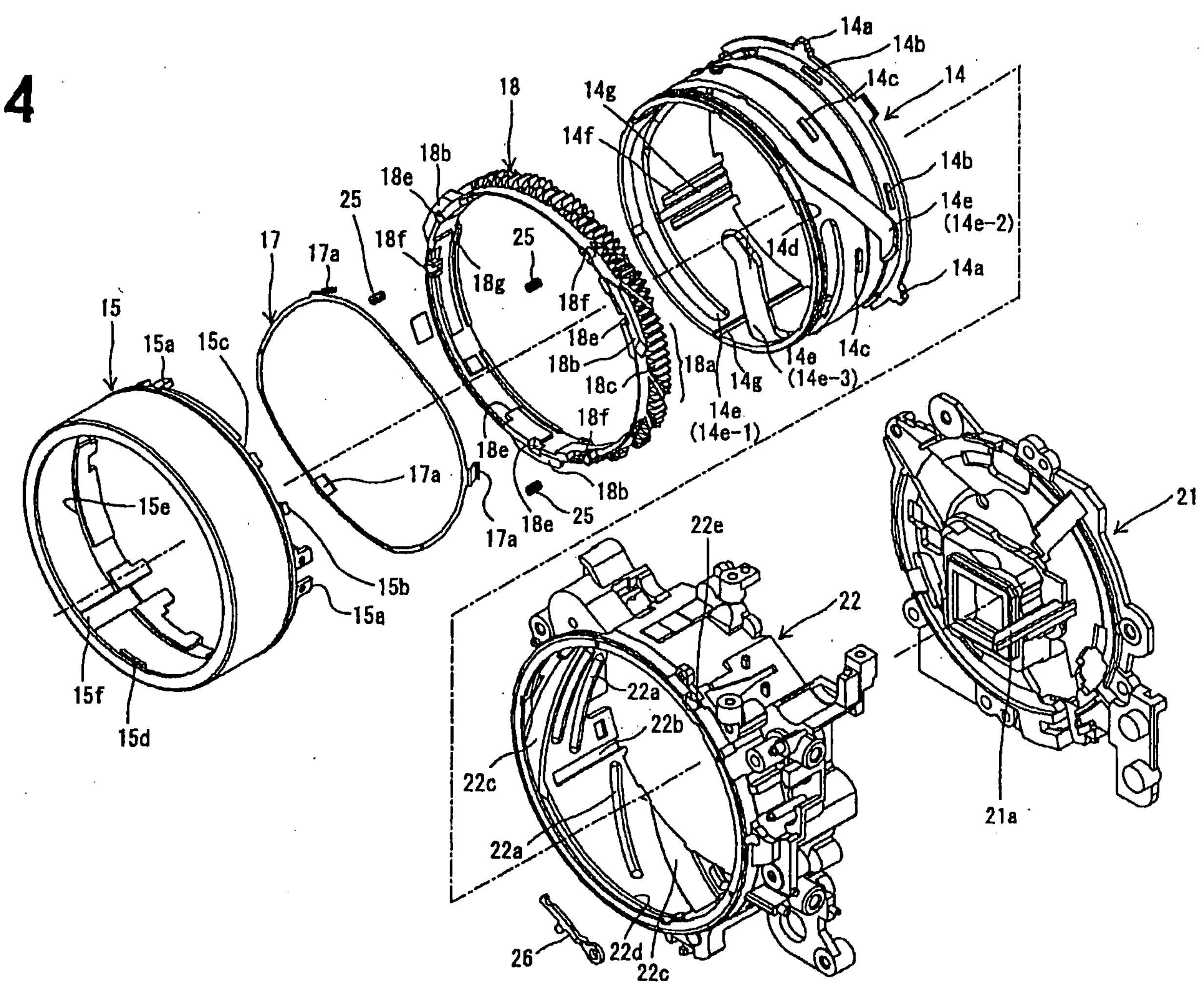

LG2
LG2
6
32
32a
11c
11
11b
11a-1
(11a)
11a-2
(11a)
11d
32a
32
6
8b-2 (8b)
8b-1 (8b)
LG2
8a
10
10a
10c
10b
10c
38
33
37
32
32a
11a-1
(11a)
39
8b-2 (8b)
8b-1
(8b)
8
35
36
66
10c
10a

Fig. 3

Fig.4



14a
14b
14c
14
14b
14e
(14e-2)
14a
14g
14f
14d
14c
14g
14e
(14e-3)
14e
(14e-1)
18
18b
18e
18f
18g
25
18f
18e
18b
18a
18c
18f
18e
18b
25
18e
17
17a
17a
17a
15
15a
15c
15e
15b
15a
15f
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22e
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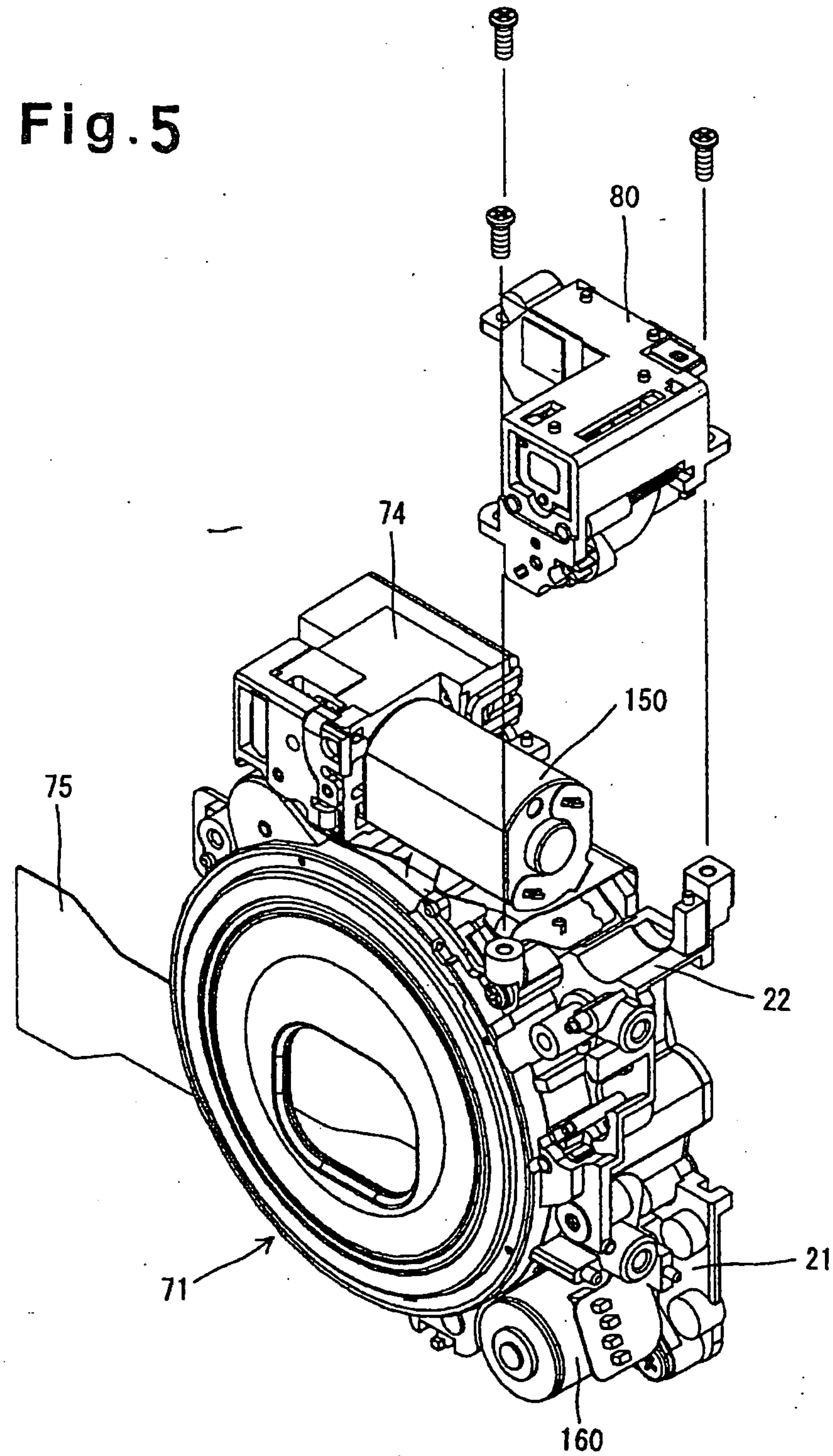
22a
22b
22c
22a
22d
22c
26
21
21a

Fig.5



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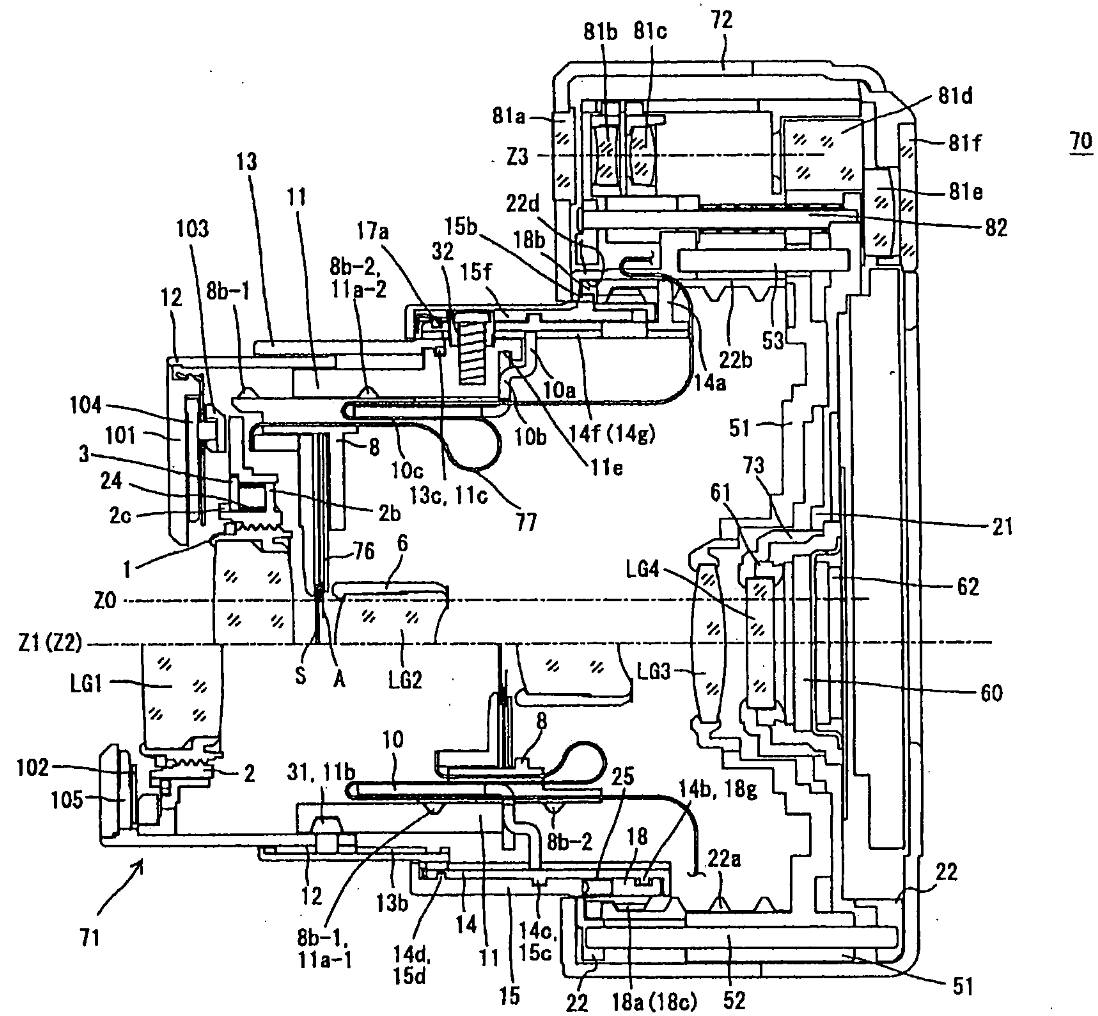
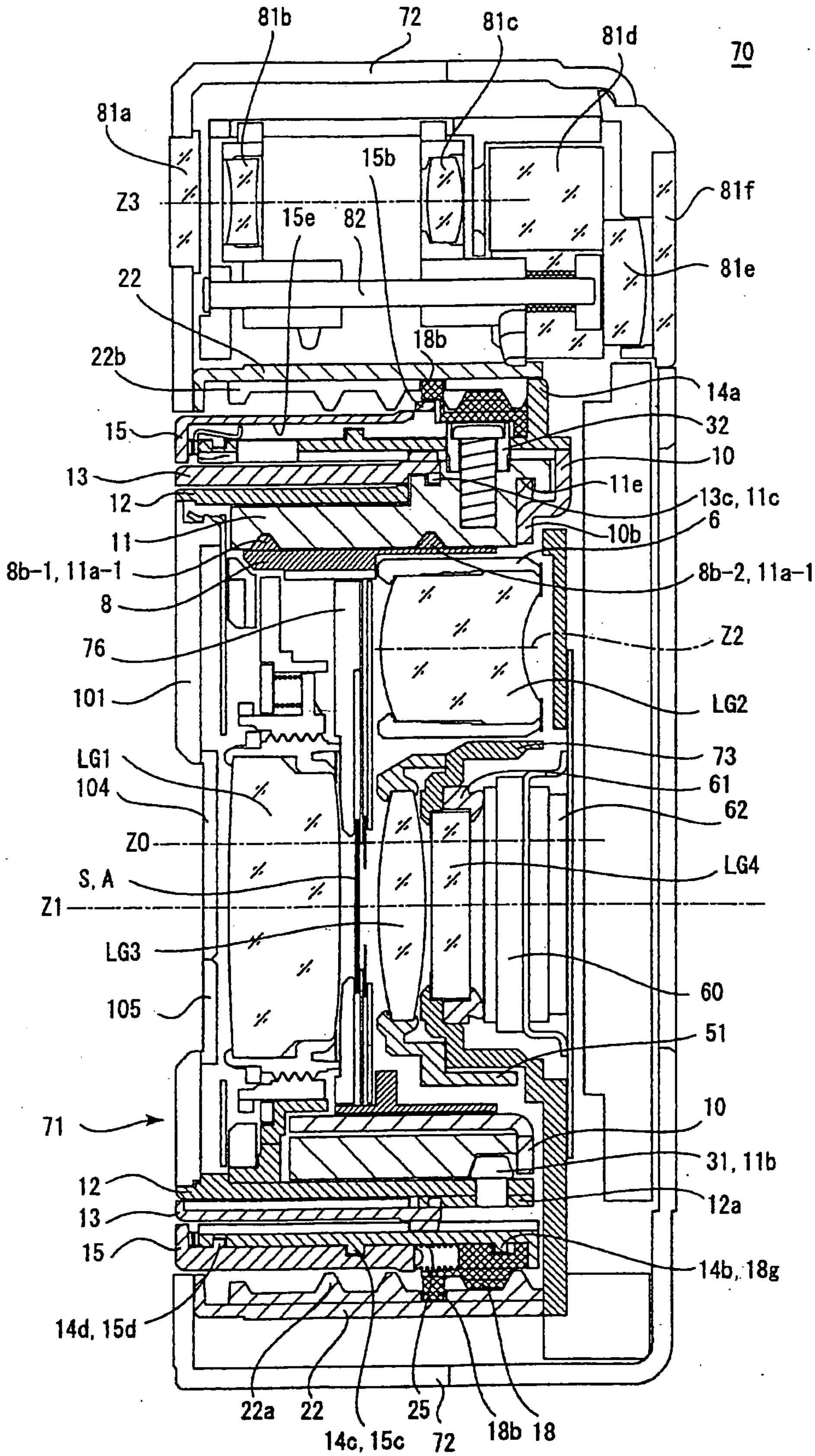


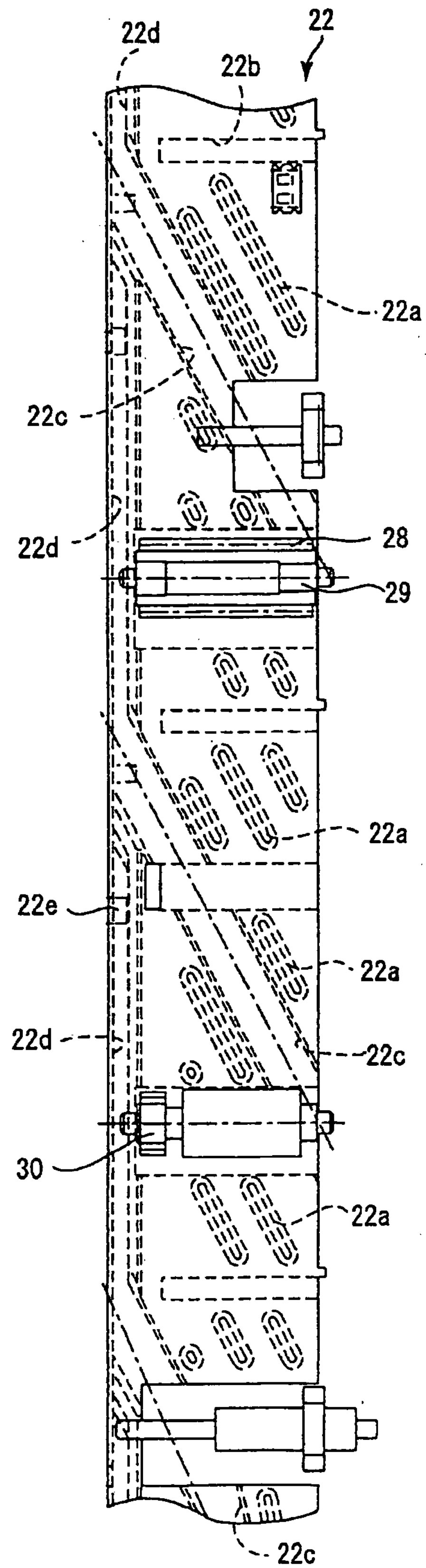
70
72
81b
81c
81a
81d
81f
81e
82
Z3
13
11
103
12
8b-1
8b-2,
11a-2
17a
32
15b
22d
18b
15f
53
22b
14a
10a
14f (14g)
10b
11e
51
104
101
3
24
2c
1
8
10c
13c, 11c
77
2b
76
6
73
61
21
LG4
62
Z0
Z1 (Z2)
S
A
LG2
LG1
LG3
60
10
102
105
2
31, 11b
8
25
14b, 18g
8b-2
18
22a
22
71
12
13b
8b-1,
11a-1
14
14d,
15d
11
15
14c,
15c
22
18a (18c)
52
51

Fig. 7



70
72
81a
81b
81c
81d
81e
81f
Z3
15b
15e
82
22
22b
18b
14a
15
32
10
13
11e
12
13c, 11c
11
10b
6
8b-1, 11a-1
8b-2, 11a-1
8
76
Z2
101
LG2
73
LG1
104
61
62
Z0
LG4
S, A
Z1
LG3
60
105
51
10
71
31, 11b
12
12a
13
15
14b, 18g
14d, 15d
22a
22
25
72
18b
18
14c, 15c

Fig. 8



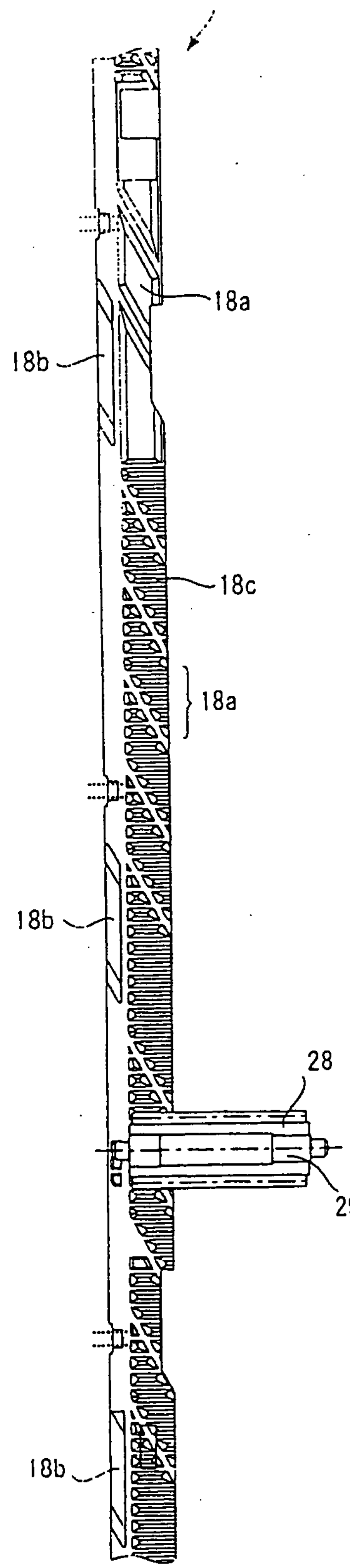


Fig. 9

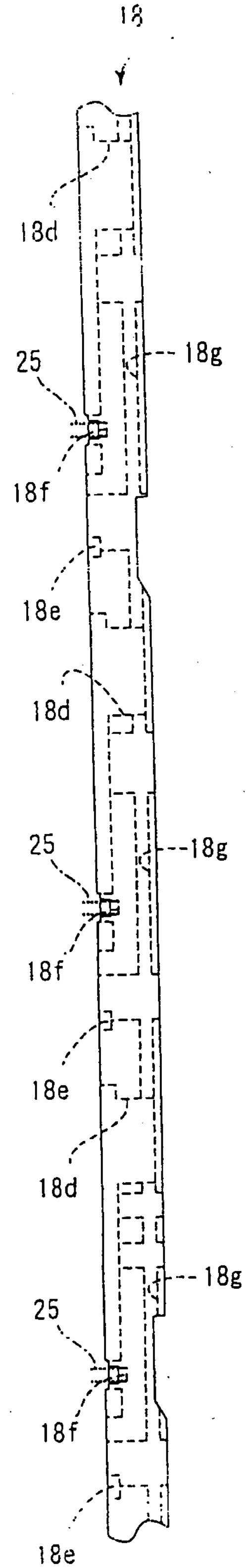
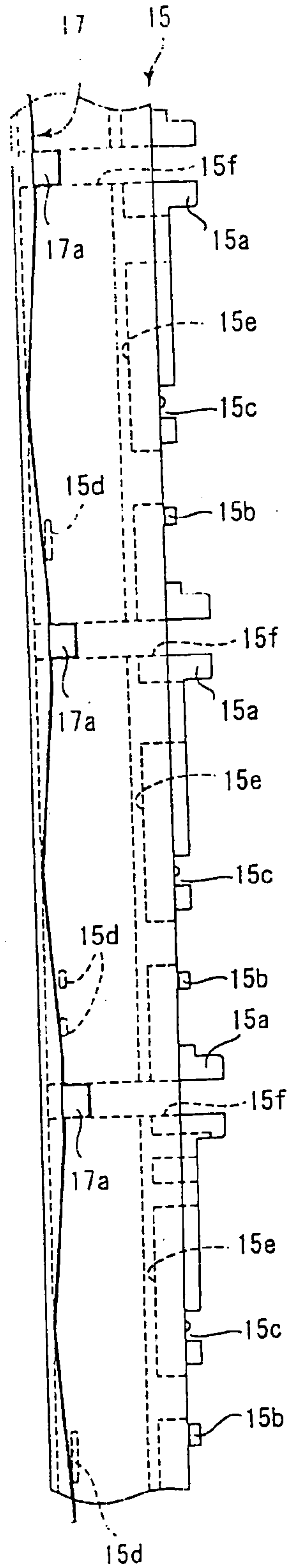


Fig. 10



17
15
15f
15a
17a
15e
15c
15d
15b
15f
15a
17a
15e
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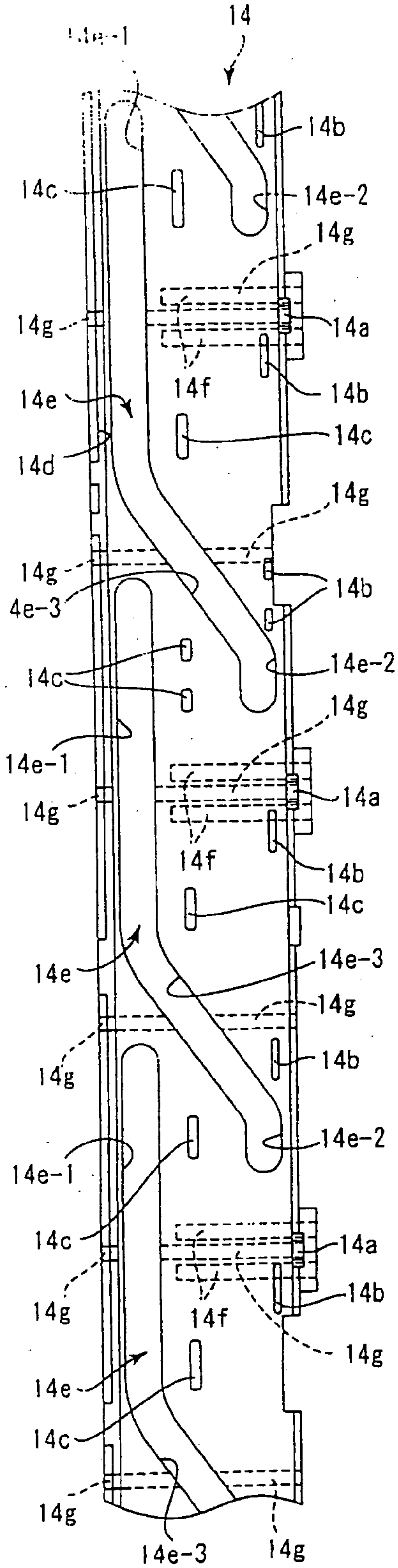
15d
15b
15a
15f
17a
15e
15c
15b
15d

Fig. 11


14
14e-1
14b
14c
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14g
14g
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14f
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14c
14g
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4e-3
14c
14e-2
14g
14e-1
14g
14a
14f
14b
14c
14e
14e-3
14g
14g
14b
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14g
14e
14c
14g
14e-3
14g

Fig. 12

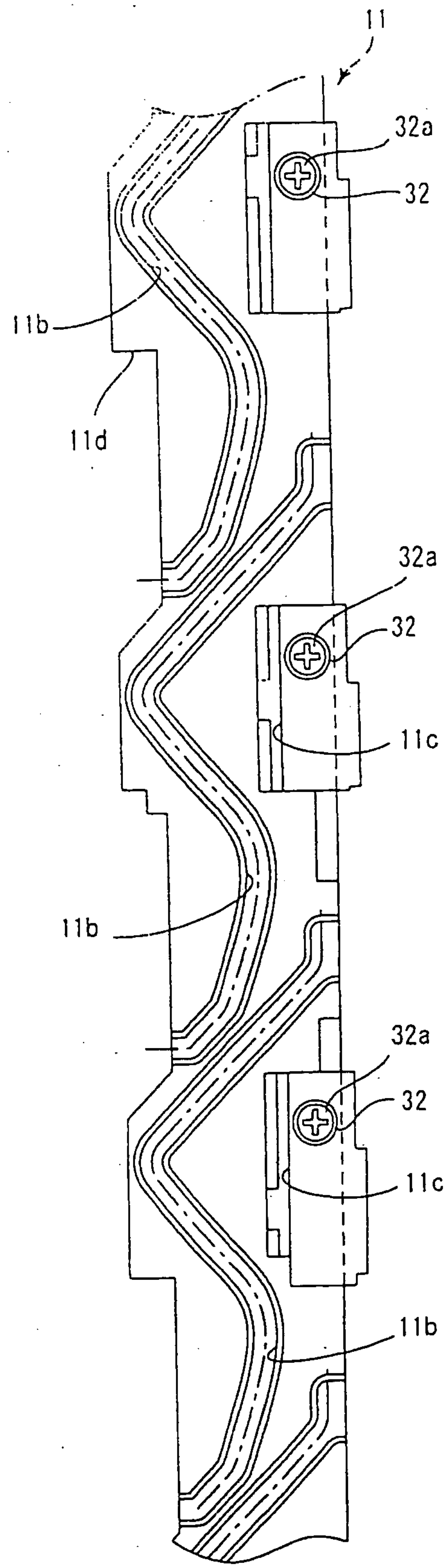
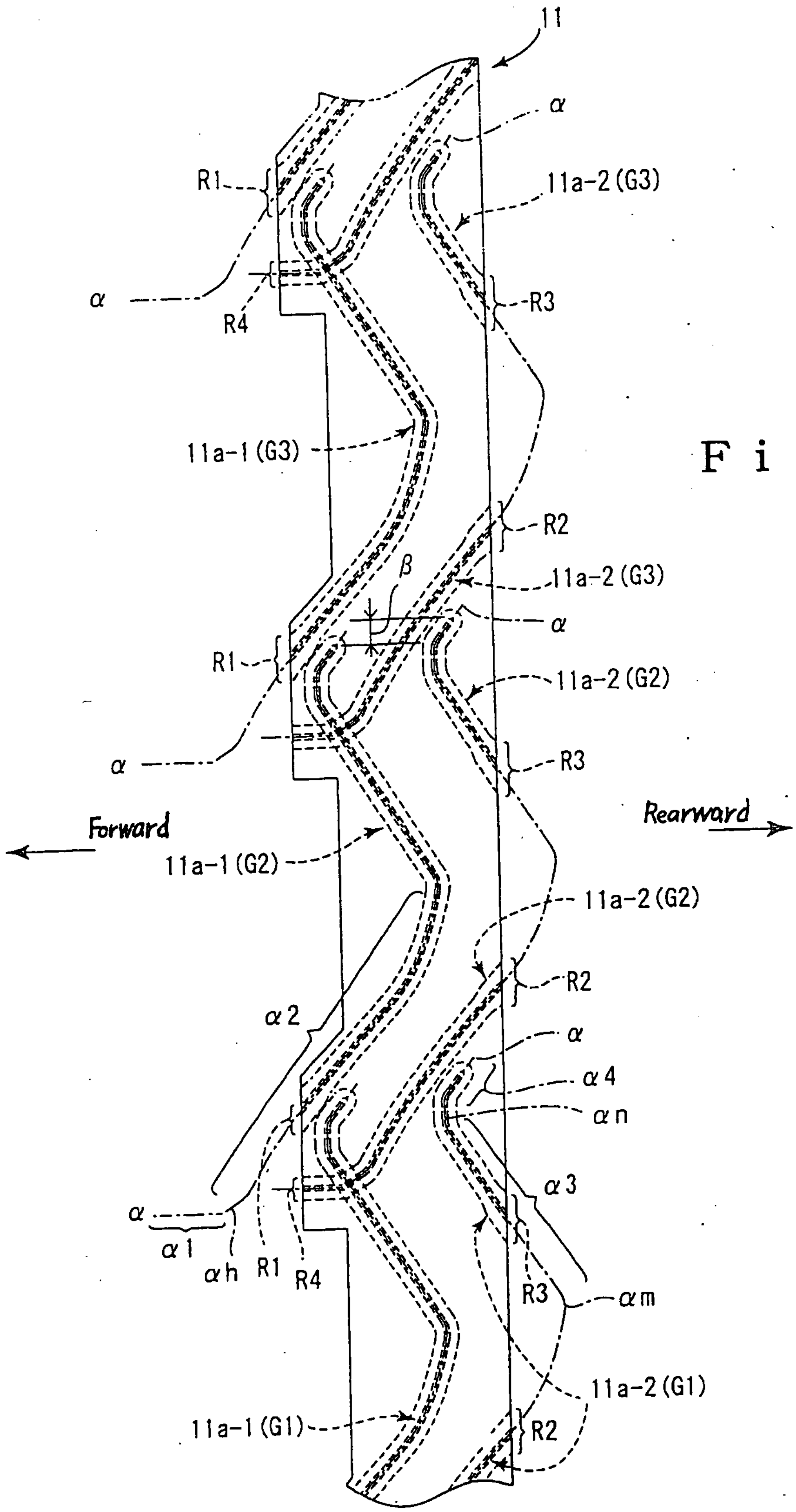


Fig. 13



11
α
11a-2 (G3)
R1
α
R4
R3
11a-1 (G3)
R2
β
11a-2 (G3)
α
R1
11a-2 (G2)
α
R3
Forward
Rearward
11a-1 (G2)
11a-2 (G2)
R2
α2
α
α4
αn
α3
α
α1
αh
R1
R4
R3
αm
11a-2 (G1)
11a-1 (G1)
R2

Fig. 14

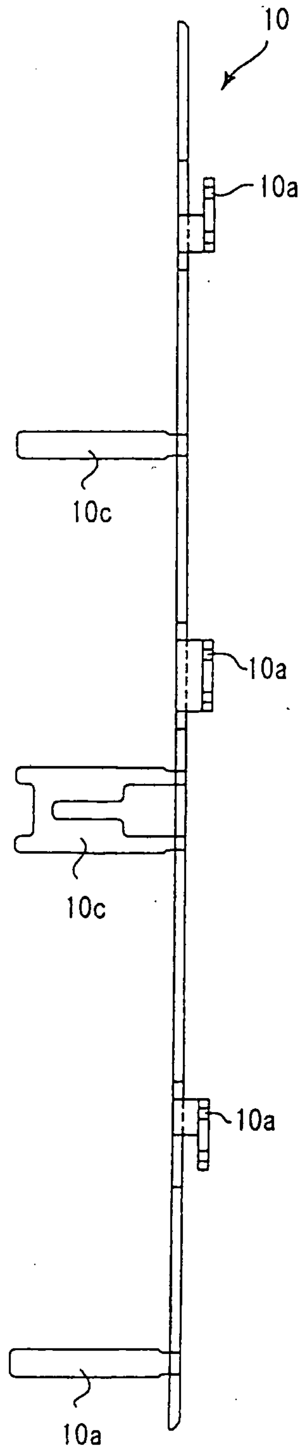


Fig. 15

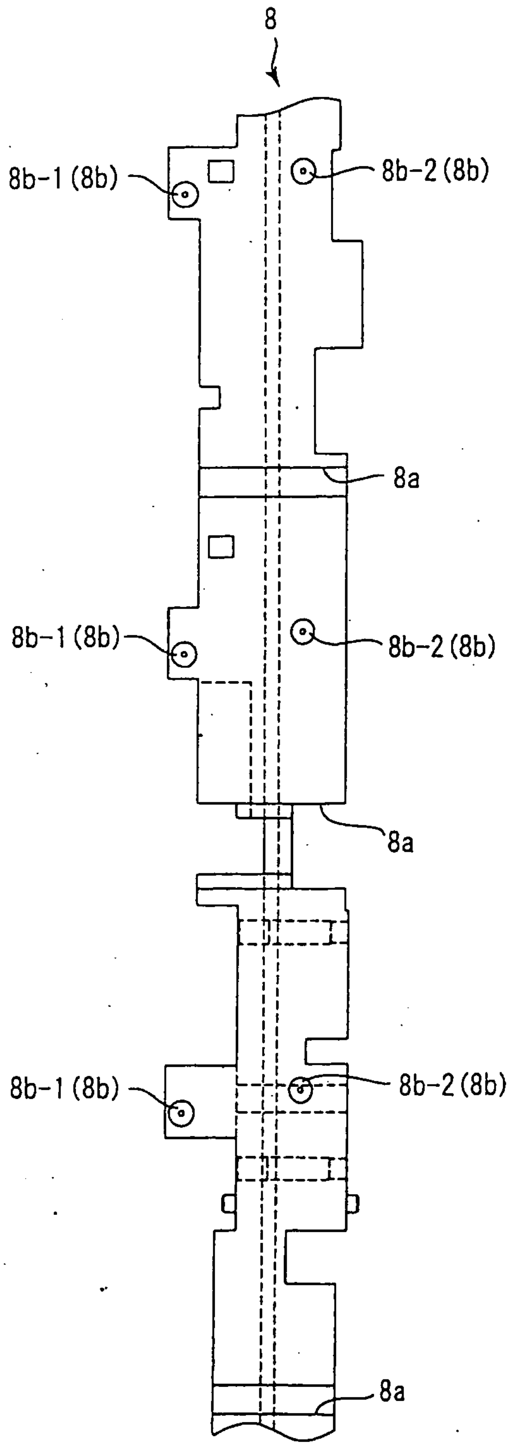
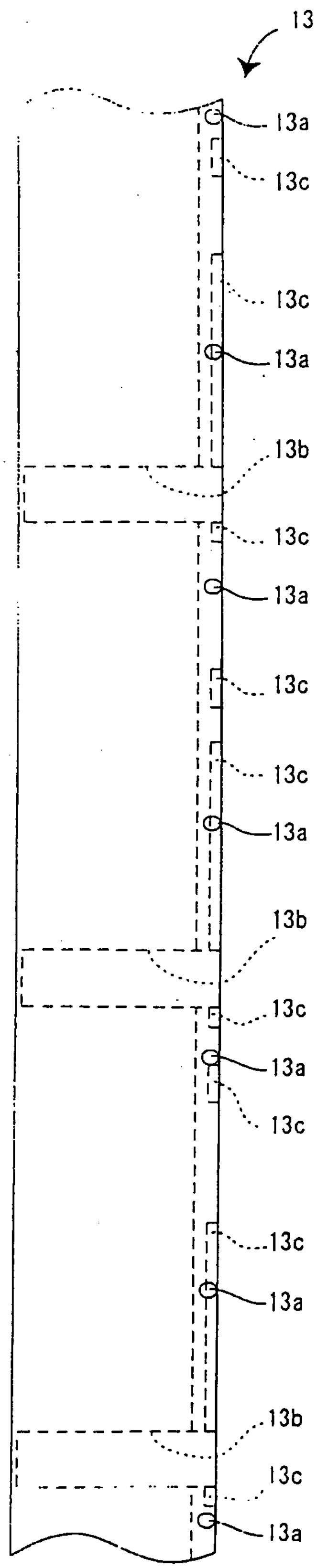


Fig. 16


13
13a
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13c
13a
13b
13c
13a
13c
13c
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13b
13c
13a
13c
13c
13a
13b
13c
13a

Fig. 17

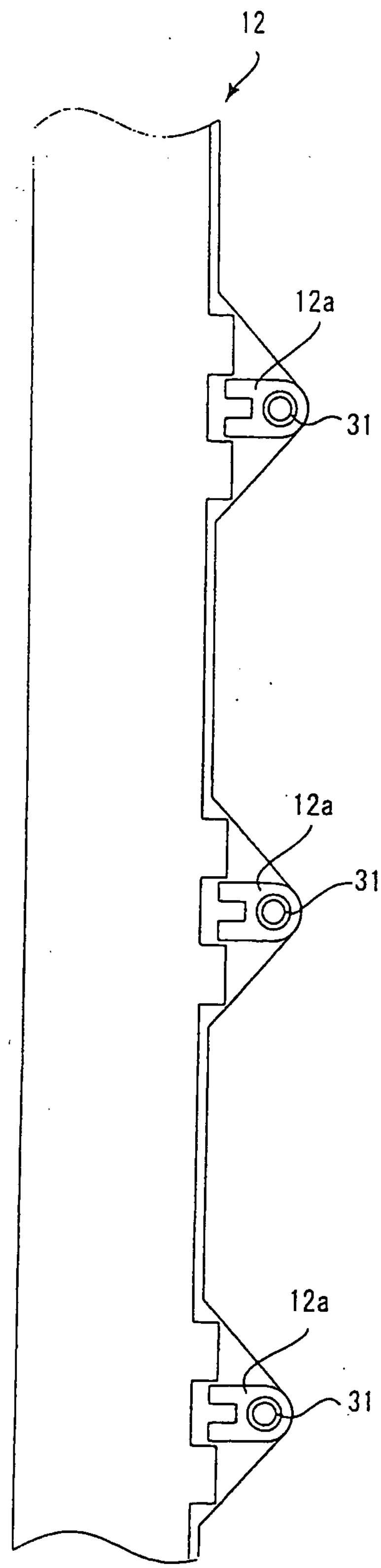

Fig. 18

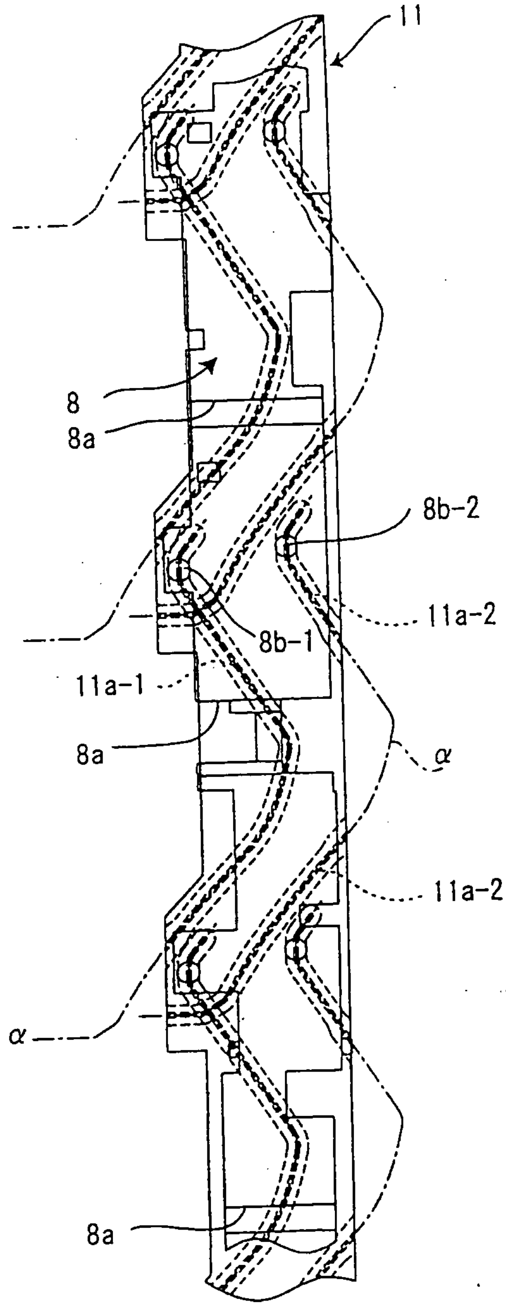

Fig. 19

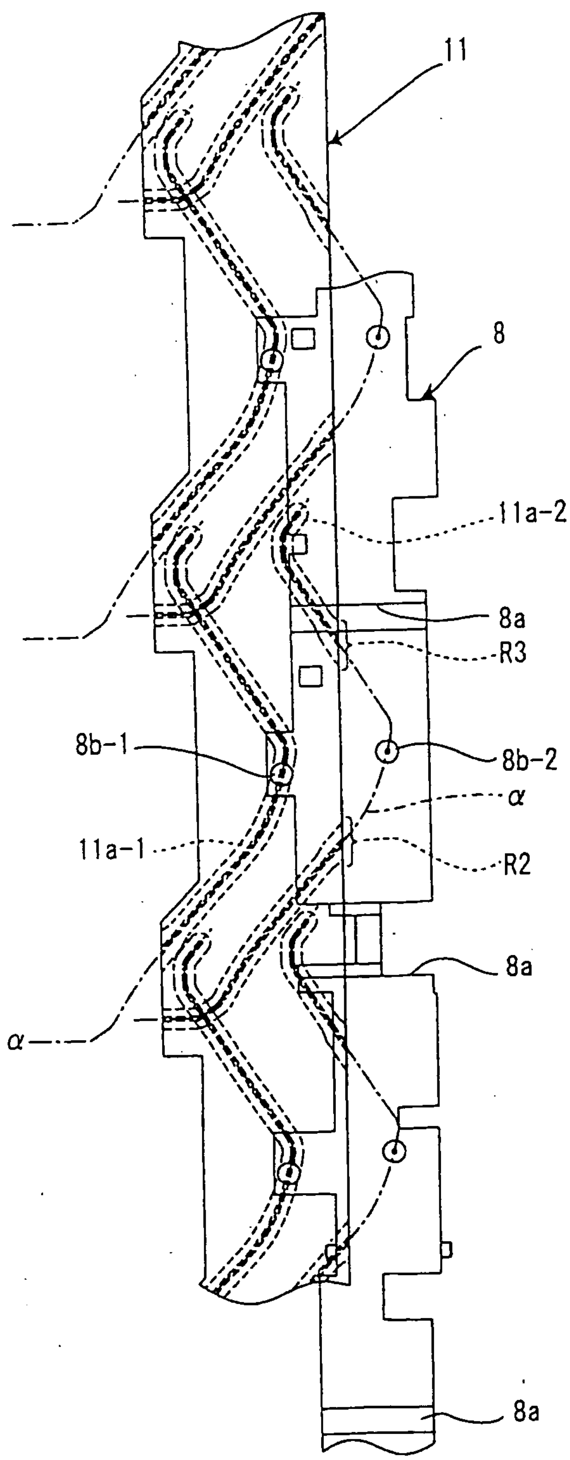

Fig. 20

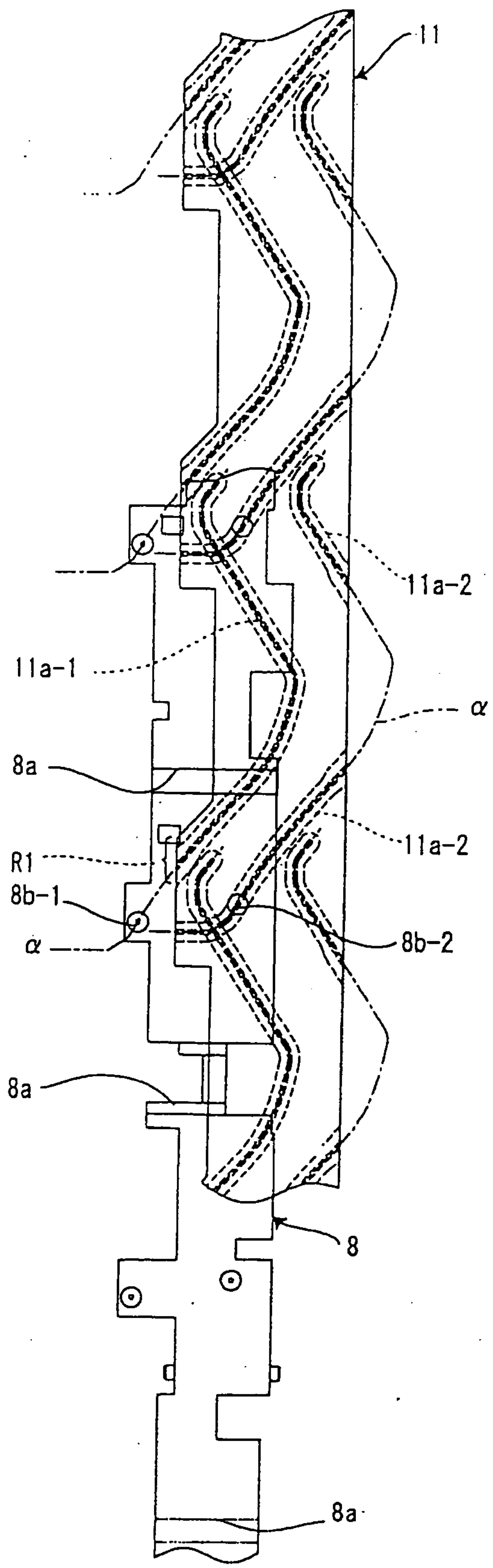

Fig. 21

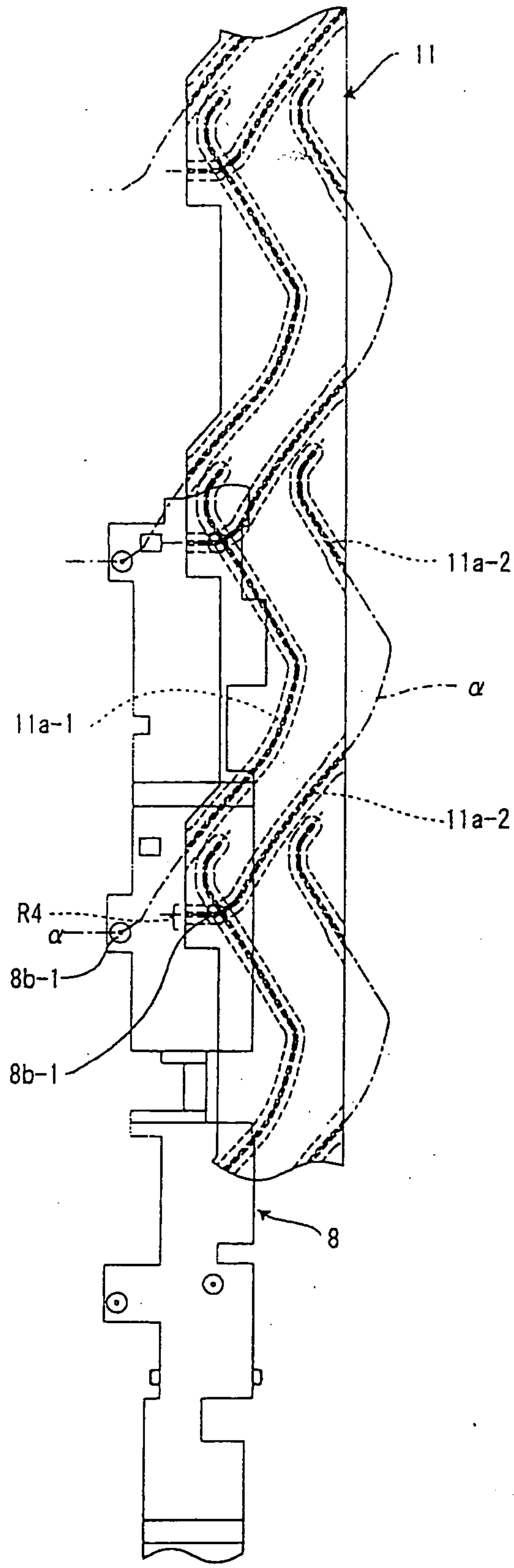

Fig. 22

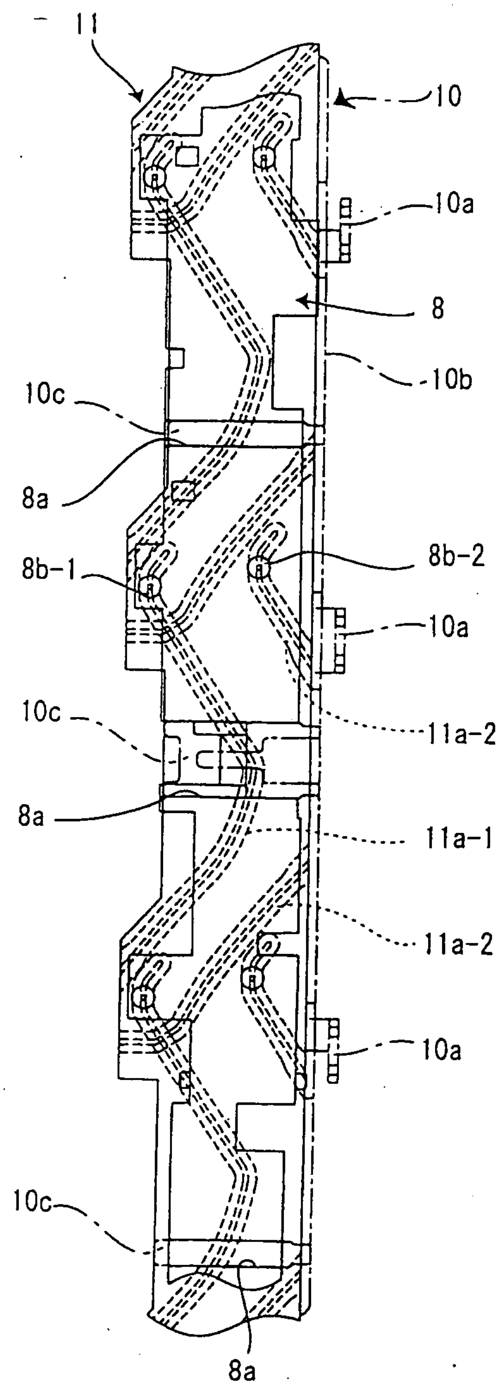
11
10
10a
8
10b
10c
8a
8b-1
8b-2
10a
11a-2
10c
8a
11a-1
11a-2
10a
10c
8a

Fig. 23

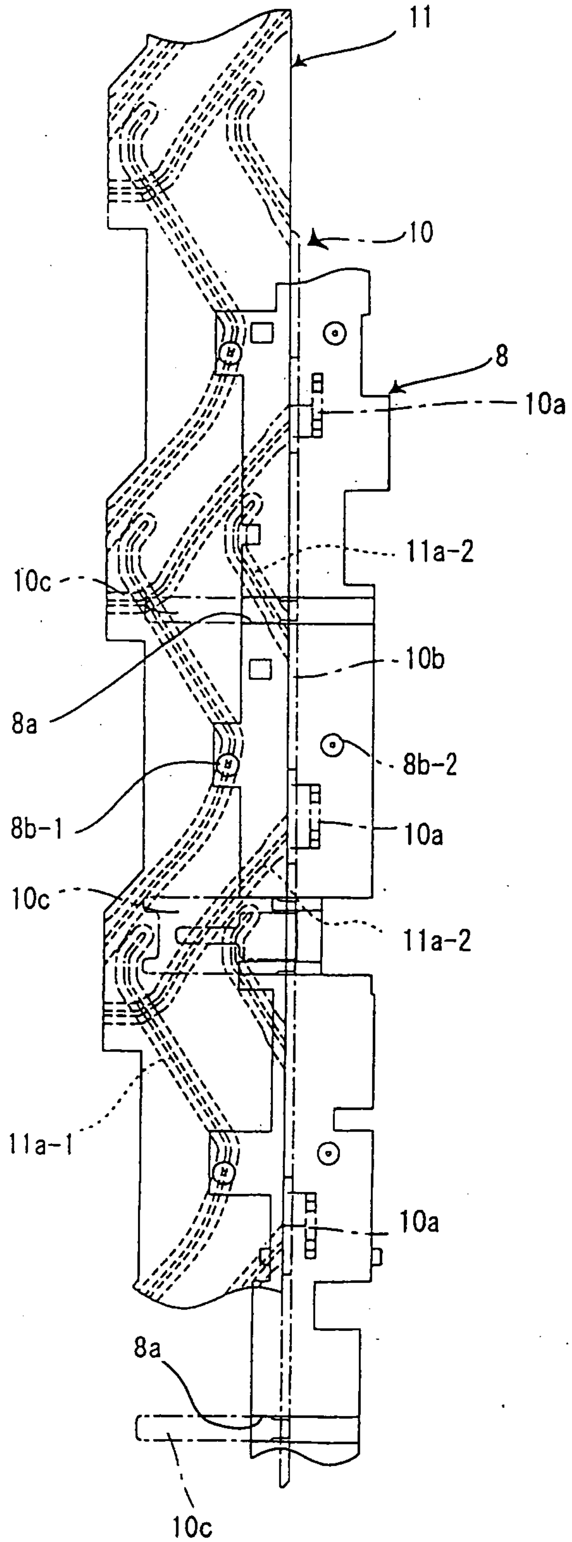

Fig. 24

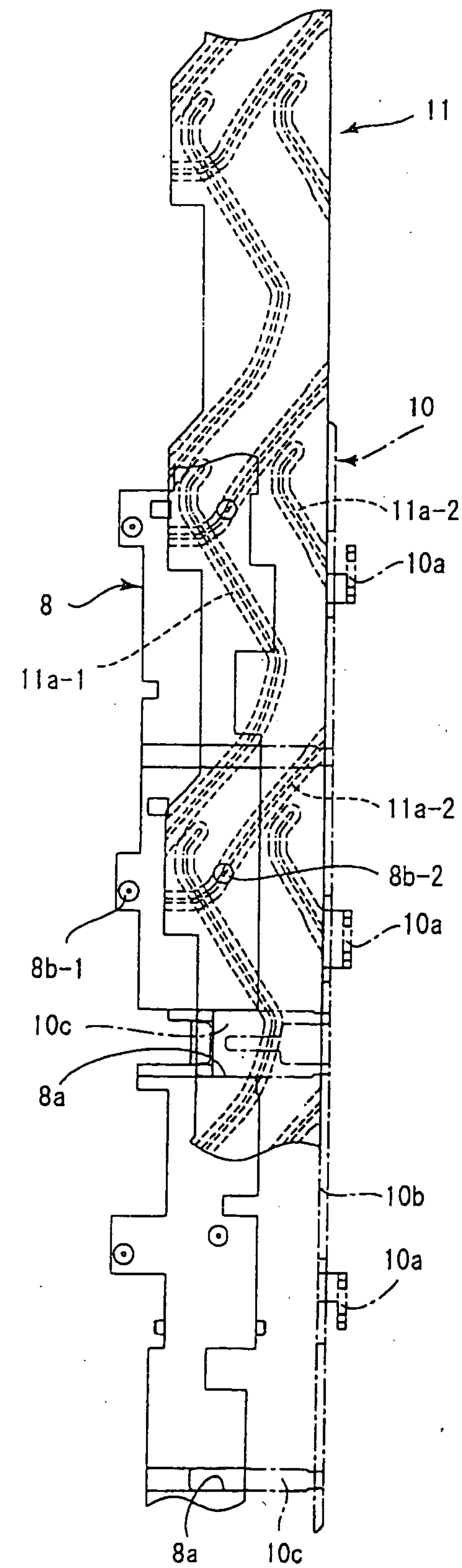

Fig. 25

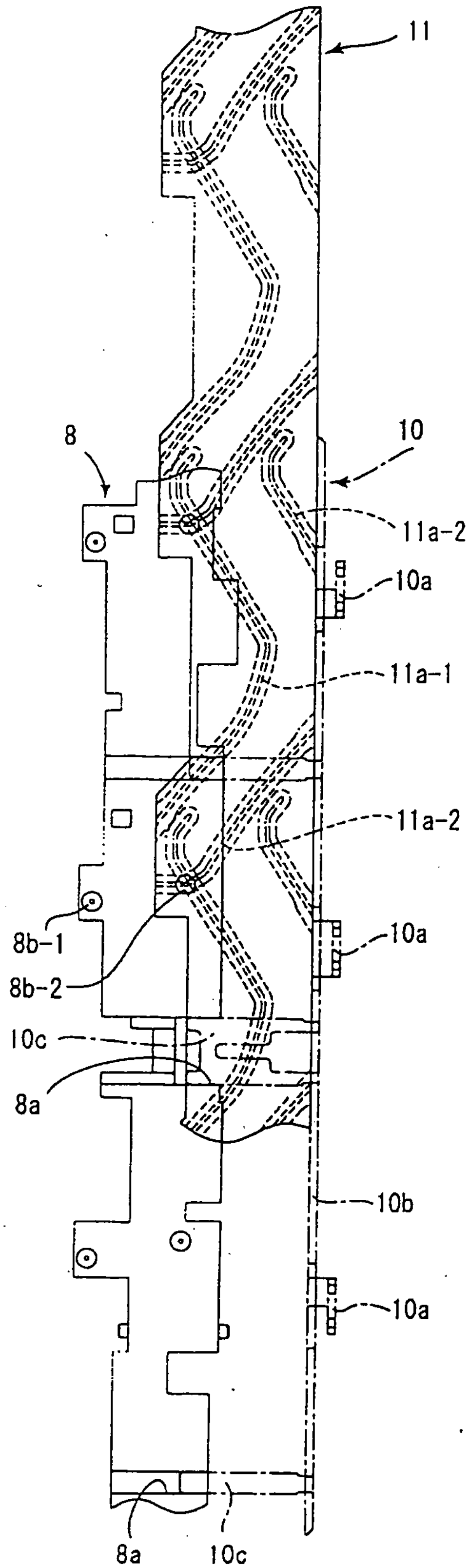

Fig. 26

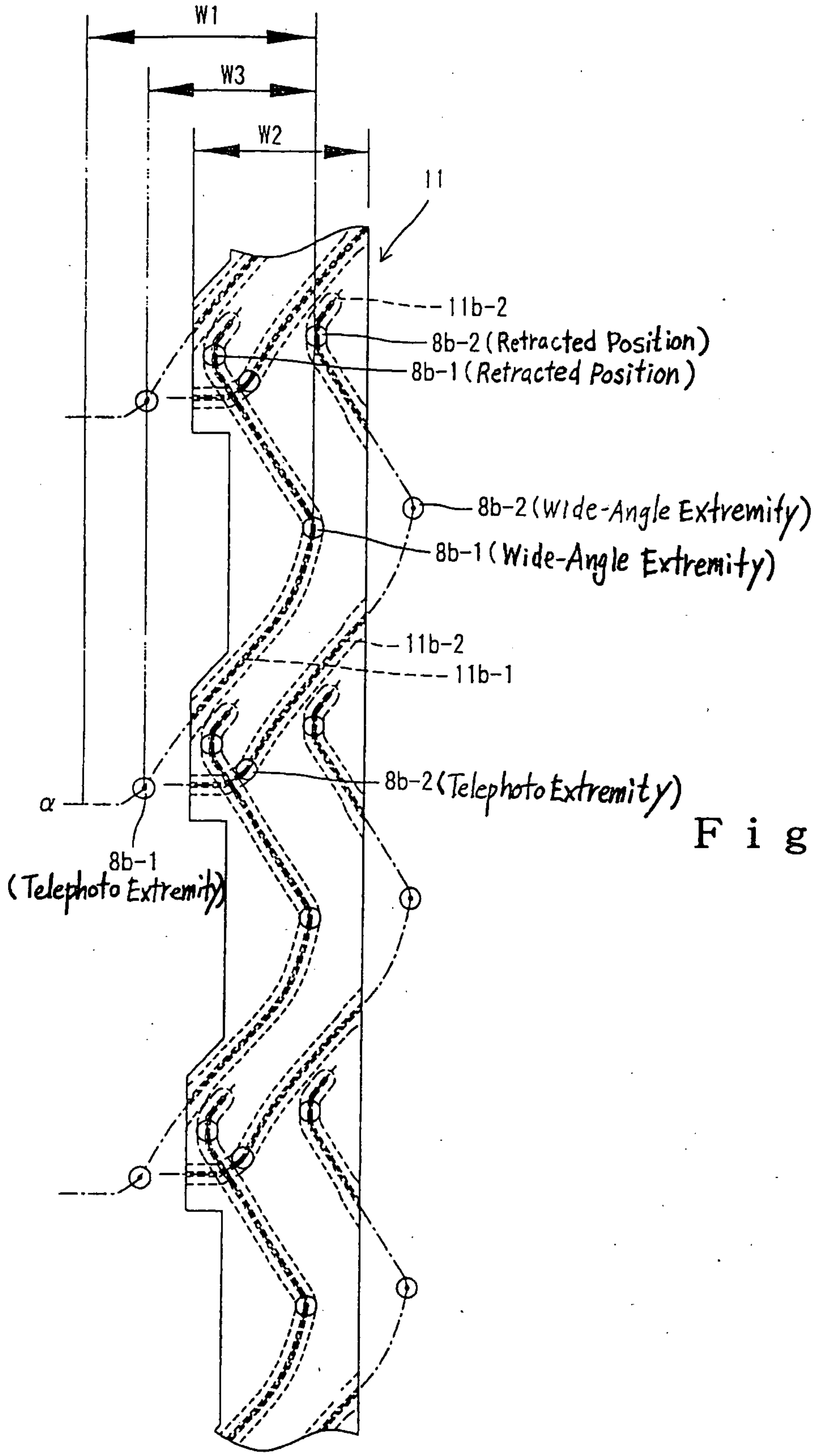
W1
W3
W2
11
11b-2
8b-2 (Retracted Position)
8b-1 (Retracted Position)
8b-2 (Wide-Angle Extremity)
8b-1 (Wide-Angle Extremity)
11b-2
11b-1
8b-2 (Telephoto Extremity)
α
8b-1
(Telephoto Extremity)

Fig. 27

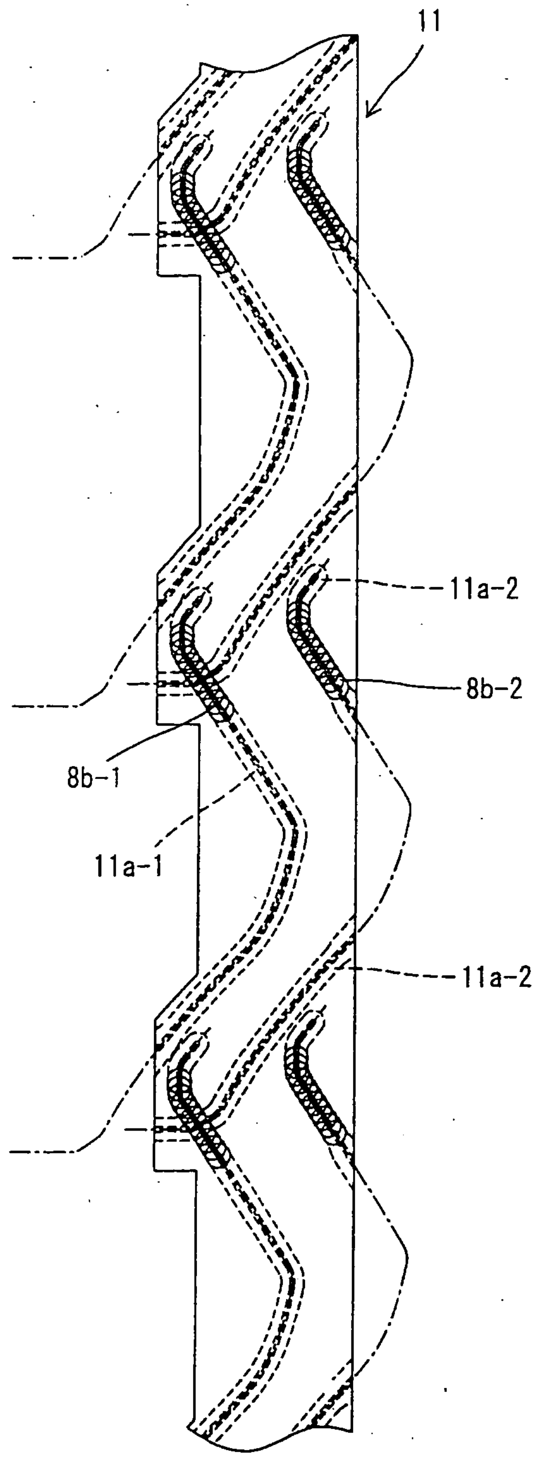

Fig. 28